

Background Document H:

**Incineration as a Land Disposal Restriction
Treatment Technology for
Chemical Agent Associated Waste**

Utah Chemical Agent Rule (UCAR)

May 1999

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**INCINERATION AS A LAND DISPOSAL RESTRICTION
TREATMENT TECHNOLOGY FOR
CHEMICAL AGENT ASSOCIATED WASTE**

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NOTATION

ACAMS	Automatic Continuous Air Monitoring System
ACWA	Assembled Chemical Weapons Assessment
AEL	airborne exposure limit
ASC	allowable stack concentration
BDAT	best demonstrated available technology
BRA	brine reduction area
BZ	3-quinuclidinyl benzilate
CAIS	chemical agent identification sets
CAMDS	Chemical Agent Munitions Disposal System
CFR	Code of Federal Regulations
CG	phosgene
CK	cyanogen chloride
CVAA	2 chlorovinylarsonous acid
DA PAM	Department of the Army Pamphlet
DAAMS	Depot Area Air Monitoring System
DCD	Deseret Chemical Depot
DFS	deactivation furnace system
DM	adamsite
DPE	demilitarization protective ensemble
DPG	Dugway Proving Ground
DRE	destruction and removal efficiency
DSHW	Division of Solid and Hazardous Waste (State of Utah)
DUN	dunnage incinerator
EA2192	S-(2-diisopropylaminoethyl) methylphosphonothioic acid
ECR	explosive containment room
EG&G	Edgerton, Germehausen, and Grier
EPA	U.S. Environmental Protection Agency
FR	Federal Registry
GA	tabun, O-ethyl, N,N-dimethyl phosphoramidocyanidate
GB	sarin, O-isopropyl methylphosphonofluoridate
GD	soman, O-pinacolyl methylphosphonofluoridate
GF	cyclohexyl methylphosphonofluoridate
h	hour(s)
H	mustard agent (purity unspecified), bis(2-chloroethyl) sulfide
HD	mustard agent (distilled), bis(2-chloroethyl) sulfide

HDC	heated discharge conveyor
HEPA	high-efficiency particulate air
HF	hydrogen fluoride/hydrofluoric acid
HL	mustard-lewisite mixture
HN1	nitrogen mustard, bis(2-chloroethyl)ethylamine
HN3	nitrogen mustard, tris(2-chloroethyl)amine
HQ	sesqui-mustard
HSWA	Hazardous and Solid Waste Amendments Act
HT	mixture of mustard (H) and agent T
HVAC	heating, ventilation, and air conditioning
JACADS	Johnston Atoll Chemical Agent Disposal System
L or L1	lewisite, 2-chlorovinylchloroarsine
L2	lewisite 2, bis(2-chlorovinyl)chloroarsine
L3	tris(2-chlorovinyl)arsine
lb	pound(s)
LDR	land disposal restriction
LDRUG	Land Disposal Restrictions — Utah Group
LIC	liquid incinerator
LO	lewisite oxide, 2-chlorovinylarsenous oxide
LOQ	limit of quantitation
MDB	munitions demilitarization building
mg/dsm ³	milligram per dry standard cubic meter
mg/m ³	milligram per cubic meter
MMD	Munitions Management Device
MPF	metal parts furnace
NRC	National Research Council
OVT	operational verification testing
PAM	pamphlet
PAS	pollution abatement system
PIC	product of incomplete combustion
PLL	Programmatic Lessons Learned
PMCD	Program Manager for Chemical Demilitarization
POHC	principal organic hazardous constituent
ppb	part(s) per billion
ppm	part(s) per million
Q	1,2-bis(2-chloroethylthio)ethane
RCRA	Resource Conservation and Recovery Act
RD&D	research, development, and demonstration

RHA	Residue Handling Area
RRS	Rapid Response System
RSM	rocket shear machine
SAIC	Science Applications International Corporation
SBCCOM	Soldier and Biological Chemical Command (U.S. Army)
SRI	Southern Research Institute
T	bis(2-chloroethylthioethyl) ether
TAP	toxicological agent protective
TGD	thickened GD
TOCDF	Tooele Chemical Agent Disposal Facility
TSDF	treatment, storage, and disposal facility
TWA	time-weighted average
UCAR	Utah Chemical Agent Rule
UEC	United Engineers and Constructors
VX	O-ethyl-S-(2-diisopropylaminoethyl) methylphosphonothioate
Vx	S-2(2-diethylamino)ethyl O-isobutyl methylphosphonothioate

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INCINERATION AS A LAND DISPOSAL RESTRICTION TREATMENT TECHNOLOGY FOR CHEMICAL AGENT ASSOCIATED WASTE

EXECUTIVE SUMMARY

Land disposal restriction (LDR) treatment standards are being proposed for chemical agents and associated wastes as part of the Utah Chemical Agent Rule (UCAR). Technology-based and concentration-based LDR treatment standards, both of which are developed on the basis of health risk considerations, are being proposed. Compliance with either the technology-based or the concentration-based standards is required as a prerequisite for placement of chemical agent treatment residues or associated wastes in land disposal units. The purpose of this background document is to support the use of incineration as an LDR technology for selected wastes.

This report provides the technical background for the demonstrated use of incineration for the treatment of specific chemical agents and chemical agent associated wastes that contain regulated hazardous constituents described in the proposed UCAR R315-2-10 and R315-2-11. The focus of this report is the chemical agents and chemical agent associated wastes encountered in the state of Utah. Information is presented on the waste-generating processes, agent associated waste characterization data, and incineration technology performance.

The basic conclusion of this document is that incineration is capable of treating chemical agents and associated wastes to meet the LDR concentration-based standards. Analytical data for the incinerator stack gas and the process residuals resulting from incineration demonstrate that the chemical agents in the waste feed were effectively destroyed and that the destruction and removal efficiencies (DREs) are greater than 99.9999%. The concentration of sarin (GB), distilled mustard agent (HD), or the nerve agent VX are effectively reduced to nondetectable levels in the process residuals and in the stack gas. Incineration of chemical agents in the other matrices is demonstrated on the basis of capability and physical/chemical characteristics, performance data on chemical agent destruction, and incineration of similar types of hazardous wastes in similar matrices.

Incineration is the current full-scale practice at the Tooele Chemical Agent Disposal Facility (TOCDF), which is located in Utah, and the Johnston Atoll Chemical Agent Disposal System (JACADS) in the South Pacific. Incineration is used for destruction of liquid agents and for decontamination of drained munitions and bulk containers with internal surfaces that have been wetted with chemical agent. Spent neutralization fluids are used in the secondary chamber of the TOCDF

and JACADS incinerators to cool the gas from the primary chamber and are effectively incinerated in this process. Demonstration of incineration is supported by the results of the Resource Conservation and Recovery Act (RCRA) trial burns conducted at TOCDF and JACADS.

Incineration is also an established practice in private industry for treatment of organic compounds similar to the chemical agents and associated wastes proposed for listing in the UCAR. Incinerability index comparisons are used to demonstrate the viability of incineration for agent associated wastes consisting of spent neutralization solutions, permeable solid materials, miscellaneous aqueous or nonaqueous liquids, spent carbon, and other residues.

Incineration of chemical agents and agent associated waste is capable of meeting or exceeding the health-based LDR concentration standards for chemical agents that are being proposed under the UCAR. Therefore, it is concluded that incineration is a demonstrated technology for chemical agents and associated wastes, as discussed herein.

1 INTRODUCTION

This background document was prepared by the Land Disposal Restrictions – Utah Group (LDRUG) established by the U.S. Army Soldier and Biological Chemical Command (SBCCOM). Its purpose is to support the Utah Department of Environmental Quality, Division of Solid and Hazardous Waste (DSHW) in developing land disposal restriction (LDR) treatment standards for chemical agents and associated wastes. The document summarizes the literature and presents a performance database to support incineration as a specified LDR technology treatment standard for chemical agent related waste streams. Incineration technology data form the basis of the majority of the treatment standards for organic constituents that have been developed by the U.S. Environmental Protection Agency (EPA) for the federal LDR program.

Science Applications International Corporation is acknowledged for assembling and analyzing the background information and for preparing an initial report on the incineration of waste streams at the Tooele Chemical Agent Disposal Facility (TOCDF). Information from the initial TOCDF report was combined with information regarding chemical agent operations at the Deseret Chemical Depot (DCD), Chemical Agent Munitions Disposal System (CAMDS), and the Dugway Proving Ground (DPG) to prepare this background document.

This section presents background information and discusses the purpose and scope of the document. It also summarizes the general approach that is taken to demonstrate that incineration qualifies as a LDR treatment technology for the subject wastes.

1.1 BACKGROUND

1.1.1 Regulatory Background

The Resource Conservation and Recovery Act of 1976 (RCRA) was intended by Congress to be a state-implemented program. The EPA was charged with developing a minimum set of standards for hazardous waste management; states would then adopt equivalent, or more stringent, regulations and seek authorization from the EPA to implement such regulations within their boundaries in lieu of the federal RCRA program. The Utah DSHW has been authorized by the EPA to operate its hazardous waste program in lieu of the federal RCRA hazardous waste program. The authorized DSHW hazardous waste program encompasses the base federal RCRA requirements, as well as several programs mandated by the Hazardous and Solid Waste Amendments of 1984 (HSWA), including the LDR program. DSHW

adopted the EPA's definitions of hazardous waste characteristics (40 Code of Federal Regulations (CFR) Part 261, subpart C)] and the EPA's listings of hazardous wastes (40 CFR Part 261, subpart D). However, because the military is a prominent industry in Utah, and because of the chemical agent missions of DCD, TOCDF, CAMDS, and DPG, in 1988, DSHW added chemical agents and associated wastes to its lists of wastes considered hazardous within the state. DSHW also added to those lists the residues from demilitarization, treatment, and testing of chemical agents. None of these materials was included on the lists of federally designated hazardous wastes previously adopted by DSHW.

Although the 1988 DSHW regulation added specific chemical agents and associated wastes to the list of hazardous wastes regulated in Utah, it did not establish LDR treatment standards for those wastes. Also, since the Utah-listed chemical agents and associated wastes were not federally designated hazardous wastes, EPA had not established federal LDR treatment standards for them. Therefore, in February 1995, DSHW announced a regulatory initiative to develop LDR treatment standards. These standards are being established as part of the Utah Chemical Agent Rule (UCAR).

1.1.2 Proposed UCAR Land Disposal Restrictions Treatment Standards

Generally, the Utah hazardous waste program requires that a waste determined to be hazardous may be land disposed only after treatment that meets applicable LDR treatment standards.

Under both the Utah and federal hazardous waste programs, there have historically been two types of LDR treatment standards: specified technology- and concentration-based standards. Where the LDR standard consists of a specified technology, wastes must be treated by the named technology. Where the concentration-based standard applies, wastes may be treated using any appropriate technology to reduce concentrations of individual hazardous constituents in the treated residue to below the levels designated in the standard. The primary advantage of a technology-based standard is that waste treatment residues do not need to be analyzed to prove that the LDR treatment standard has been met. The primary advantage of a concentration-based standard is that any appropriate technology, including emerging and innovative technologies, can be applied to treat the waste, as long as residual constituent concentration levels comply with the concentration-based standards.

To establish federal LDR treatment standards, EPA first identifies wastes with similar physical and chemical properties. Next, EPA categorizes the similar wastes into groups with similar treatability characteristics. EPA then evaluates technologies used to treat the wastes in these "treatability groups" to find the best

demonstrated available technology (BDAT) for each treatability group (EPA 1994). Once the BDAT has been identified for a waste treatability group, EPA uses performance data from operation of the BDAT and other information to set an appropriate LDR treatment standard for wastes in the group. Such treatment standards may be expressed as concentration-based standards, a specified technology, or a combination of the two. Most often, EPA-established LDR treatment standards take the format of concentration-based standards.

DSHW has elected to use a risk-based approach for deriving the LDR treatment standards. The constituent concentration levels proposed as LDR treatment standards for chemical agent related wastes in the UCAR proposal were derived with a modeling approach. The methodology for the risk-based approach is explained in Section XI, "Development of Health-Based Waste Management Concentration Levels," of the proposed UCAR Preamble.

The UCAR proposal also advances an innovation in LDR treatment standard formats. Instead of expressing LDR treatment standards for chemical agent related wastes in *either* the constituent concentration level format *or* the specified technology format (as do the federal RCRA regulations), where possible, the UCAR proposal provides LDR treatment standards in *both* formats, as alternatives to one another. The UCAR proposal would allow the generator of a chemical agent related waste to choose the most appropriate LDR treatment standard from among the established alternatives.

To be designated as a specified technology LDR treatment standard for a particular chemical agent related waste, a treatment technology must be capable of treating the particular waste to meet the concentration-based LDR treatment standards. Therefore, the concentration-based standard and any specified technology standards for each chemical agent related waste are based on risk. In this manner, regardless of the LDR treatment standard format that the generator chooses to comply with for a specific waste stream, protection of human health and the environment is ensured. One advantage of having LDR treatment standards in alternative formats is that when a specified technology format is chosen, repeated and expensive analyses are avoided. If emerging and innovative technologies become available, such technologies can be used by choosing the concentration-based standard.

1.2 PURPOSE AND SCOPE

This background document assesses the capability of incineration to treat various chemical agent related wastes to meet the LDR concentration-based standards. It concludes that incineration qualifies for designation as a specified technology LDR treatment standard for most of the chemical agent related wastes

proposed to be listed by DSHW under the hazardous waste codes P901 through P910 and K901 through K908. The rationale for the listings is provided in Preamble Section VIII, "Hazardous Waste Relistings – Process Wastes." Such waste streams are generated by the U.S. Army chemical agent operations in Utah, including those at DPG, DCD, CAMDS, and TOCDF. Section 1.3 provides a general description of these wastes; additional information is presented in Section 2.

This document does not address LDR treatment standards for any chemical included in the proposed UCAR that is listed by the EPA as hazardous waste in 40 CFR 261.33 [i.e., cyanogen chloride (CK) (P033), phosgene (CG) (P095), hydrogen fluoride/hydrofluoric acid (HF) (U134), and chloroform (U044)]. EPA's LDR treatment standards, as specified in 40 CFR 268, are adopted by Utah in R315-13 for these chemicals. Similarly, several of the chemicals addressed by the UCAR contain arsenic as a hazardous constituent, including lewisite (L) and adamsite (DM). Because arsenic is identified as a toxicity characteristic constituent in EPA's regulations, which DSHW has adopted, EPA's LDR standards for arsenic must be met for these compounds if the waste fails the toxicity characteristic for arsenic. EPA's LDR standards, as specified in 40 CFR 268, are adopted in R315-13 for these chemicals.

This document also does not support designation of incineration as a specified technology LDR treatment standard for DM (U901) and 3-quinuclidinyl benzilate (BZ) (U902). A concentration-based LDR standard is not available for these compounds, and, also, only limited data about incineration of these compounds are available. Furthermore, although lewisite (P905) could be incinerated and will meet the LDR concentration-based standard, the Army intends instead to apply a chemical neutralization technology for this agent.

For a number of Utah-listed chemical agent related wastes for which this background document supports designation of incineration as a specified LDR treatment standard, other technologies are also capable of treating the wastes to meet the concentration-based standards. Additional background documents have been prepared supporting designation of these other technologies as additional specified LDR technologies. Also, the Army is examining a number of new technologies that may prove capable of qualifying as specified LDR technologies. For example, several technologies are being evaluated as part of the Army's Assembled Chemical Weapons Assessment (ACWA) program. The proposed UCAR includes a quick action mechanism for designating new technologies as a specified technology.

1.3 GENERAL WASTE DESCRIPTION

The chemical agents that are stored by the Army in Utah as part of the national stockpile become wastes when they are removed from storage for demilitarization and at that time meet the definition of a "P" hazardous waste or a "U" hazardous waste. Because the chemical agent stockpile in Utah is to be destroyed and because testing and evaluation procedures ultimately result in chemical agent destruction, all chemical agents and associated waste streams eventually become hazardous wastes under Utah rules. These process waste streams become identified as specific "K" code wastes. A general discussion of where and how the process streams are generated is in Section 2.

Table 1.1 lists all the hazardous chemicals that are listed or proposed for listing as hazardous constituents. The residues from the demilitarization, testing, and treatment of chemical agents become hazardous process wastes designated by a "K" code because they typically or frequently contain (or at one time contained) hazardous constituents. The following is a description of the "K" codes; more detail can be found in Preamble Section VIII, "Hazardous Waste Relistings – Process Wastes:"

- **K901** - Spent chemical neutralization solutions (including solids or particulates contained therein) used to neutralize chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K902** - Miscellaneous, physically solid, nonpermeable materials, such as glass or metal, that were contaminated with chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K903** - Miscellaneous physically solid, permeable materials, such as spent laboratory, monitoring, and testing materials (including syringes, tubing, rags and wipes, gloves, aprons, and protective suits), wood, plastics, and organic materials, that were contaminated with chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K904** - Miscellaneous aqueous or nonaqueous liquid materials, such as antifreeze, refrigerants, and hydraulic fluids, that were contaminated with chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K905** - Spent carbon from both air filtration equipment and personal protective equipment that were contaminated with chemical(s) listed in R315-2-11(e)(1) or (f)(1).

TABLE 1.1 Hazardous Constituents

Common Name(s)	Chemical Abstracts Name	Chemical Abstracts No.	Hazardous Waste No.
GB, Sarin	O-Isopropyl methylphosphonofluoridate	107-44-8	P901
GD, Soman	O-Pinacolyl methylphosphonofluoridate	96-64-0	NA.
GA, Tabun	O-Ethyl N,N-dimethyl phosphoramidocyanidate	77-81-6	P902
GF	Cyclohexyl methylphosphonofluoridate	329-99-7	NA
VX	O-Ethyl S-(2-diisopropylaminoethyl) methylphosphonothioate	50782-69-9	P903
H, HD, Mustard Gas	Bis(2-chloroethyl) sulfide	505-60-2	P904
L, L1 Lewisite, Lewisite 1	2-Chlorovinylchloroarsine	541-25-3	P905
HN1	Bis(2-chloroethyl)ethylamine	538-07-8	P906
HN3	Tris(2-chloroethyl)amine	555-77-1	P907
HL	Mixture of H and L	506-6-2 and 541-25-3	P908
HQ	Mixture of H and Q	506-6-2 and 3563-36-8	P909
HT	Mixture of H and T	506-6-2 and 63918-89-8	P910
DM, Adamsite	Phenylarsazine chloride	578-94-9	U901
Q-Mustard	1,2-Bis(2-chloroethylthio)ethane	3563-36-8	NA
T-Mustard	Bis(2-chloroethylthioethyl) ether	63918-89-8	NA
L2, Lewisite 2	Bis(2-chlorovinyl)chloroarsine	40334-69-8	NA
L3, Lewisite 3	Tris(2-chlorovinyl)arsine	40334-70-1	NA
EA2192	S-(2-diisopropylaminoethyl) methylphosphonothioic acid	73207-98-4	NA
LO, Lewisite Oxide ^b	2-Chlorovinylarsenous oxide	3088-37-7	NA
Vx	S-2(2-diethylamino)ethyl O-isobutyl methylphosphonothioate	159939-87-4	NA
CK ^c	Cyanogen chloride	506-77-4	P033
CG ^c	Phosgene	75-44-5	P095
BZ	3-Quinuclidinyl benzilate	13004-56-3	U902
HF ^c	Hydrogen fluoride/Hydrofluoric acid	7664-39-3	U134
Chloroform ^c	Trichloromethane	67-66-3	U044
Arsenic ^c	Arsenic	7440-38-2	NA

^a NA = not applicable.

^b LO hydrolyzes to 2-chlorovinylarsenous acid (CVAA) in aqueous systems.

^c These chemicals are already regulated as hazardous constituents under RCRA; the proposed rule will not affect these listings.

- **K906** - Ash, cyclone residue, and baghouse dust from incineration of chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K907** - Slag and refractory generated from incineration of chemical(s) listed in R315-2-11(e)(1) or (f)(1).
- **K908** - Brine salts, liquids, solids, and sludges generated from pollution abatement systems, including those used in conjunction with incineration or chemical neutralization, employed in operations with chemical(s) listed in R315-2-11(e)(1) or (f)(1).

1.4 GENERAL APPROACH FOR DEMONSTRATING LDR TECHNOLOGIES

To qualify as applicable under the UCAR, a specified LDR technology must be capable of treating the waste in question (i.e., "P" waste or "K" waste) to meet the concentration-based LDR standards proposed as part of the UCAR. The intent of this document is therefore to demonstrate that incineration is capable of:

- Reducing the concentration of the chemical agents that make up the "P" wastes to concentration-based LDR standards, and
- Reducing the concentration of hazardous constituents potentially present within "K" wastes (except for DM, BZ, and the EPA listed chemicals CK, CG, HF, chloroform, and arsenic) to concentration-based LDR standards.

The Army has amassed a large amount of data demonstrating that incineration is capable of destroying specific chemical agents in pure form (e.g., munitions grade) and in specific waste matrices (the "K" wastes). However, the Army does not currently possess data regarding the effect of incineration on all the hazardous constituents that are addressed in the UCAR. For example, while the Army has data on incineration of VX, data are not available for Vx or for EA2192, a degradation product of VX. Therefore, the approach taken in this background document to demonstrate that incineration is capable of treating chemical agents and associated wastes to meet the proposed concentration-based LDR treatment standards has the following components:

- Information is presented indicating that, on the basis of physical-chemical properties, incineration is capable of treating specific P901-P910 chemical agents and the associated K901-K908 waste

streams to meet the proposed LDR concentration-based standards. This information is presented in Section 3.

- Data are presented from incineration of chemical agents at the Army's Johnston Atoll Chemical Agent Disposal System (JACADS) in the South Pacific and at TOCDF in Utah demonstrating that the LDR concentration-based standards are met for these chemicals. Available data are presented for GB, VX, and HD in Section 4.
- EPA did not possess treatment data for all the hazardous waste constituents in all the waste matrices necessary to develop LDR treatment standards. In order to develop concentration-based standards for the LDR regulations, EPA relied on establishing treatability groups for all the hazardous wastes regulated under the RCRA program. These treatability groups consist of waste types that are similar in terms of physical and chemical characteristics. EPA would then examine the wastes within the treatability groups and develop LDR concentration-based standards for all the wastes in the group on the basis of available data for a subset of the chemicals. A similar approach is applied in this background document —treatability groups are established on the basis of the chemical agents and waste matrices for which data are available (Section 4). Treatability groups are established in Section 5.

Section 6 presents conclusions regarding incineration as an applicable treatment technology.

2 INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

This section describes the industry affected by the proposed rule, outlines the processes used at the DCD, TOCDF, CAMDS and DPG, and provides general waste characterization information.

2.1 INDUSTRY AFFECTED

The industry affected by the proposed UCAR consists of the U.S. Army facilities located in Utah that are involved in storage, testing, and demilitarization operations with chemical agent materials. The wastes subject to the proposed regulation will be generated from operations at DCD, TOCDF, CAMDS, and DPG. Also included are wastes generated from nonstockpile operations in Utah, such as the demilitarization of the chemical agent identification sets (CAIS) through the Rapid Response System (RRS) and operation of the Munitions Management Device (MMD) for the demilitarization of recovered chemical munitions.

The chemical agent stockpile stored at DCD is permitted under RCRA to be processed at TOCDF. DCD also generates wastes from cleanup of spills from leaking munitions or containers while in storage. Processing of the chemical agent stockpile at TOCDF results in the generation of chemical agent associated wastes with the listed codes K901 through K908. CAMDS is a research and test facility for the development of methods of demilitarization and treatment of chemical munitions. CAMDS operates under a RCRA research, development, and demonstration (RD&D) permit, and the facility includes incinerators for the destruction of chemical agents. CAMDS has submitted a full RCRA operating permit application to DSHW for a portion of its operations, and a draft permit is being prepared. The types of wastes generated at CAMDS are similar to those produced at TOCDF. DPG conducts tests of chemical warfare defensive material, such as detectors, monitors, and protective clothing. These tests are primarily performed using surrogate agents; however, small quantities of chemical agents are used in laboratory and fully contained test chamber settings.

Chemical agent associated wastes also will be produced from future operations of the RRS and the MMD at nonstockpile locations. The RRS and the MMD, which are now in the RD&D phase, use specialized decontamination solutions to detoxify a wide range of chemical agents and mixtures of the various chemical agents. Resulting wastes from these systems are to be incinerated and/or treated using approved methods at a commercial RCRA treatment, storage, and disposal facility (TSDF). Details of the processes can be found in the following two documents, which are available in DSHW's public information facility in Salt Lake City, Utah: State of Utah Department of Environmental Quality, Division of Solid and Hazardous Waste, *Resource Conservation and Recovery Act (RCRA)*,

Hazardous Waste Treatment Part B Permit for Rapid Response System (RRS); and State of Utah Department of Environmental Quality, Division of Solid and Hazardous Waste, Draft Resource Conservation and Recovery Act (RCRA), Research, Development, and Demonstration (RD&D) Permit for Munitions Management Device Version I (MMD-1).

Table 2.1 shows the type of chemical agents stored at each of the Army facilities in Utah. Not included are the chemical agents in the CAIS and in recovered munitions, which are to be processed by the RRS and MMD, respectively. While RRS and MMD spent chemical neutralization solutions are defined as K901 spent neutralization solutions, these K901 wastes differ from other K901 wastes in that they do not meet LDR concentration-based standards as generated. DSHW is proposing an LDR technology of incineration for these K901 spent neutralization solutions, as discussed herein.

TABLE 2.1 Chemical Agent Storage by Location

Chemical Agent Category	Chemical Agent Acronym	Storage Site ^a			
		DPG ^b	DCD	CAMDS	TOCDF
Nerve Agents	GA	X	X	X	X
	GB	X	X	X	X
	GD	X			
	TGD	X			
	GF	X			
	VX	X	X	X	X
	Vx	X			
Blister Agents	H/HD	X	X	X	X
	HL	X			
	HT	X	X	X	X
	HQ	X			
	L	X	X	X	
	HN1	X			
	HN3	X			

^a An "X" indicates that the chemical agent may be stored, tested, or demilitarized at that facility.

^b Quantities of chemical agents at DPG are limited and are used for research and testing.

2.2 PROCESS DESCRIPTIONS AND WASTE STREAMS

2.2.1 Deseret Chemical Depot (DCD)

2.2.1.1 Process Description

The chemical agent stockpile stored at DCD consists of various projectiles, ton containers, rockets, bombs, mines, and spray tanks. The bulk of the chemical agent stockpile stored at DCD consists of GB, HD, and VX, with smaller amounts of H, HT, GA, and lewisite (L). The total agent weight in the stockpile was originally estimated to be 13,616 tons.

Experienced and trained workers monitor the storage areas. Regular inspections are performed to monitor for leaks and inspect the condition of the weapons and facilities. The majority of the agent related process "K" waste is generated from neutralization and cleanup operations as a result of leaking munitions and containers or from spent activated carbon filters.

2.2.1.2 Waste Streams

Table 2.2 provides a brief description of the individual chemical agent associated waste streams that are generated from storage operations at DCD.

2.2.2 Tooele Chemical Agent Disposal Facility (TOCDF)

2.2.2.1 Process Description

The TOCDF treatment process is based on disassembly of munitions followed by separation and destruction of individual components by incineration. The initial processing step involves disassembly with the removal of explosives and draining of the chemical agent from projectiles or the draining of chemical agent from ton containers. The drained agents are incinerated in the liquid incinerator (LIC). The deactivation furnace system (DFS) processes drained rockets and mines, and the explosive components of the munitions. The metal parts furnace (MPF) thermally decontaminates all drained ton containers and drained munitions

TABLE 2.2 DCD Process Waste Streams

Waste Stream	Waste No.	Currently Treated by Incineration?
Waste chemicals	P901-P910	Yes. Treated at TOCDF
Neutralization fluid	K901	No. Off-site TSDF
Miscellaneous metal parts	K902	No. Off-site TSDF
Plastics	K903	No. Off-site TSDF
Soil	K903	No. Off-site TSDF
Spent activated carbon	K905	No. On-site storage
Spent silver fluoride pads	K903	No. Off-site TSDF
Spill cleanup material	K903	No. Off-site TSDF
Trash, debris, and protective clothing	K903	No. Off-site TSDF
Water/groundwater	K904	No. Off-site TSDF

other than rockets and mines. The dunnage incinerator (DUN) was designed to incinerate contaminated dunnage. A more detailed description of the operation follows.

Disassembly and Draining

The disassembly and draining process for munitions consists of initial removal of the explosive components followed by draining of chemical agent. The projectile/mortar disassembly machine is used to remove fuses and bursters. These explosive elements are punched or sheared to expose sufficient surface area to prevent detonation in the DFS. All explosive-handling operations are conducted in an explosive containment room (ECR) designed to withstand detonation. Following removal of fuses and bursters, the munitions are moved to the munitions processing bay, where the burster well is removed from the projectile body using a multipurpose demilitarization machine. Following disassembly, the liquid chemical agent is drained from the munitions.

Rockets are punched and drained in the ECR. A punch unit pierces each rocket while it is still in its fiberglass launch tube, and the bulk of the agent content is drained. A rocket shear machine (RSM) in the ECR then cuts the rockets into eight segments, separating the fuse from other explosive elements, and dividing both the burster and the rocket propellant into segments. The shear machine also is used to shear projectile bursters into fragments that can be safely incinerated.

Land mines are manually unpacked from their drum containers, then punched and drained. The explosive charge of the mines is not removed from the mine body. Instead, the charge is punched to expose sufficient surface area to prevent

detonation during incineration. Bulk items, including ton containers, spray tanks, and nonexplosively configured bombs, are punched and drained at a bulk drain station. Chemical agent from these items and all other munitions is pumped to liquid agent storage tanks located in a toxic cubicle.

Liquid Chemical Agent Incineration

Two LICs are used at TOCDF to ensure availability of adequate processing capability. Each LIC consists of two refractory-lined combustion chambers. Liquid chemical agent from agent storage tanks is pumped at a uniform, continuous rate to the LIC burner, where it is atomized and injected into the primary chamber. The chemical agent, the air used to atomize the agent, combustion air, and natural gas auxiliary fuel are the primary feeds to the chamber. Combustion is maintained at approximately 1,482°C (2,700°F) by the controlled addition of agent, fuel (natural gas), and air. The exhaust gas (flue gas) from the primary chamber enters the secondary chamber. Spent aqueous neutralization solutions or water is sprayed through an atomizing nozzle into the top of the secondary chamber to cool the primary gas to approximately 1,093°C (2,000°F). A natural gas fixed burner maintains the secondary chamber at approximately 1,093°C (2,000°F) to allow thermal destruction of organic materials in the spent neutralization solution. The exhaust gas is then directed to the LIC pollution abatement system (PAS).

Spent chemical neutralization solutions do not require incineration as an LDR technology. These solutions from within the TOCDF facility are reused within the secondary chamber to cool the gas from the primary chamber and are incinerated in the process. Spent chemical neutralization solutions from laboratory operations at TOCDF are not treated in this manner.

Deactivation Furnace System

The DFS consists of a rotary kiln and an afterburner. The waste feed to the DFS includes the explosive components of the munitions along with the associated fuses, booster cups, burster tubes, rocket and launch tube segments, and small quantities of residual chemical agent. The DFS feed materials drop from the ECR to the DFS through a feed chute. Explosives, propellants, and residual agent are incinerated in the DFS kiln. The treated metal parts and fiberglass materials exit the DFS through an electrically heated discharge conveyor (HDC). Feed materials are retained in the kiln for about 12 minutes and in the HDC for an additional 15 minutes. The kiln and HDC are maintained above 538°C (1,000°F) to ensure decontamination to the Army's 5X requirements (see Section 2.3 for definition of 5X). DFS combustion gases pass through a blast attenuation duct and into the cyclone, where large particles are separated from the gas stream. The gas stream

continues through a slagging afterburner that operates at approximately 1,204°C (2,200°F) and into the DFS PAS through refractory-lined ducts.

Metal Parts Furnace

The MPF consists of a horizontal, three-chamber, roller hearth unit and an afterburner. The primary chamber of the MPF has three separate firing zones through which the drained munitions and ton containers are conveyed. Temperatures are maintained between 649°C (1,200°F) and 927°C (1,700°F). The design of the MPF meets the Army's minimum 5X treatment requirement of a temperature of 538°C (1,000°F) and a residence time of 15 minutes (see Section 2.3 for definition of 5X). Decontaminated metal parts are transferred to the discharge tray unloading conveyor. Primary chamber exhaust gases pass through the MPF afterburner for completion of combustion. The afterburner is a horizontal, refractory-lined cylindrical vessel equipped with natural gas burners. The afterburner maintains the flue gas received from the primary chamber at approximately 1,093°C (2,000°F) for a minimum residence time of 0.5 second for completing chemical agent destruction. The flue gas leaving the afterburner flows to the MPF PAS through a refractory-lined duct.

Pollution Abatement System

Each furnace is supported by a PAS of similar design, which cools and scrubs the exhaust gases and removes particulates and acid gases before they are discharged through a common stack. The PAS consists of a quench tower, a venturi scrubber, a packed-bed scrubber, a candle-type mist eliminator vessel, brine/quench recycle pumps, and an induced-draft blower. Scrubber brine is produced from the quenching and acid scrubbing of the exhaust gases. The brine is processed in the brine reduction area (BRA), which consists of evaporators to concentrate the brine and drum dryers that produce a dry salt stream. Entrained particulates from the BRA are collected in a baghouse before the exhaust is discharged to the atmosphere.

2.2.2.2 Waste Streams

Chemical agent associated wastes are produced from the various unit processes of the TOCDF plant. Chemical munitions and bulk items are processed in a series of operations called campaigns. Each campaign is dedicated to operations involving a single chemical agent. Since only one campaign is run at a time, wastes generated during a campaign only contain a single chemical agent at

a time. In addition, to ensure that only one agent is encountered in wastes, the buildings and treatment units are decontaminated during the changeover period from one campaign to another.

Table 2.3 presents a brief description of the individual chemical agent associated waste streams that are generated from demilitarization operations at TOCDF. A summary description of the waste streams originating from the main process unit follows. These wastes listings are based on the operating experience of TOCDF and the JACADS facility.

LIC Waste Streams

The waste streams generated from the LICs include slag and refractory brick. Slag is generated in the secondary chamber of the LICs from the incineration of chemical agent. The slag is in a molten state in the furnace and is drained into refractory-lined drums on a periodic basis and allowed to solidify. The slag may contain metals and may exhibit the RCRA toxicity characteristic. Refractory brick waste is generated when the refractory lining (along with the mortar used to bind the brick) of the LIC chambers deteriorates over time and is replaced. The refractory brick used at TOCDF is an alumina-chrome brick composed of alumina, chromium oxide, and other metal oxides.

DFS Waste Streams

HDC ash, cyclone residue, and refractory are expected to be the major waste streams from the DFS. HDC ash is produced from the incineration of rockets, propellants, and explosives, and includes coarse solids exiting the DFS kiln. Finer solids entrained in the DFS kiln exhaust are collected in the cyclone as cyclone residue. Both HDC ash and cyclone residue are generated on a continuous basis. DFS waste refractory is not expected to be produced in as large a quantity as LIC waste refractory, which is known to undergo a higher deterioration rate. Both ash and cyclone residue may contain metals and may exhibit the RCRA toxicity characteristic.

MPF Waste Streams

The primary waste streams generated from the MPF are the treated metal parts from the incineration of drained munitions and bulk items (such as bombs, spray tanks, and ton containers). The MPF metal parts are expected to be a significant waste stream from TOCDF in terms of volume. The metal parts exiting the MPF

TABLE 2.3 TOCDF Waste Streams

Waste Stream	Waste No.	Currently Treated by Incineration?
Waste chemicals	P901-P910	Yes, except for lewisite
Brine reduction area baghouse residue	K908	No. Off-site TSDF
Brine salts	K908	No. Off-site TSDF
Brine tank sludge	K908	No. Off-site TSDF
Neutralization fluid	K901	Yes, except for laboratory operations
Deactivation furnace system (DFS) cyclone residue	K906	No. Off-site TSDF
DFS heated discharge conveyor (HDC) ash	K906	No. Off-site TSDF
DFS refractory	K907	No. Off-site TSDF
Demilitarization protective ensemble (DPE) suits	K903	No. Permitted long-term storage
Laboratory liquid wastes	K901, K904	No. Off-site TSDF
Laboratory solid wastes	K902, K903	No. Off-site TSDF
Liquid incinerator (LIC) refractory	K907	No. Off-site TSDF
LIC slag	K907	No. In state TSDF
Miscellaneous metal parts	K902	Yes.
Mist eliminator filter/demister candles	K902, K903	No. Off-site TSDF
Metal parts furnace (MPF) ash	K906	No. Off-site TSDF
MPF metal	K902	Yes.
MPF refractory	K907	No. Off-site TSDF
MPF residue	K902, K903	No. Off-site TSDF
Pollution abatement system (PAS) brine	K908	No. Off-site TSDF
PAS brine sump sludge	K908	No. Off-site TSDF
PAS quench tower residue	K908	No. Off-site TSDF
Plastics	K903	No. Permitted on-site storage
Residue Handling Area (RHA) baghouse residue	K906	No. Off-site TSDF
Spent activated carbon	K905	No. Permitted on-site storage
Spent hydraulic fluid	K904	Yes.
Spent silver fluoride pads	K903	No. Off-site TSDF
Spill cleanup material	K903	Yes.
Trash, debris, and protective clothing	K903	No. Permitted on-site storage
Waste oil	K904	Yes.
Wooden pallets	K903	No. Permitted on-site storage

undergo treatment equivalent to the 5X criterion (see Section 2.3 for description of 5X). No explosives are processed in the MPF, only chemical agent wetted metal parts.

PAS Waste Streams

Scrubber brine is the major aqueous waste stream produced from the individual PAS systems for scrubbing flue gases from the three main furnace systems at TOCDF. The brine is a major waste stream by volume and is composed of salts formed by the neutralization of acid gases and excess caustic soda. The brine tanks may include drainage from demisters and precipitation runoff. Mist eliminator filters are produced as waste from the capture of particulates (including metal oxides) in the demister units of the PAS. Residue generated in the quench tower and solutions produced from the cleaning of the PAS units also are possible wastes from the PAS. Sump water and sump sludge are generated from the cleaning of spills in the PAS area.

BRA Waste Streams

The main waste stream generated from the BRA operations is brine salt, which is the largest waste stream produced at TOCDF. Baghouse residue, sludge, and wastewater generated from cleaning BRA equipment are other possible waste streams from BRA operations. Brine salt is generated from the evaporation and drum drying of scrubber brine produced from the PAS units. These salts may contain metals as inorganic salts and may exhibit the RCRA toxicity characteristic.

Laboratory Waste Streams

Both solid and aqueous wastes (primarily K901, K902, K903 and K904) are generated from laboratory operations involving the analysis of chemical agent in samples from plant operations. Solid wastes could include silver fluoride pads, glassware, tubing, and syringes. Aqueous and nonaqueous liquid wastes include solvents, acids, and spent neutralization solutions.

Other Wastes Streams

In the demilitarization process, several major waste streams are produced that are not direct products of treatment units, but that are potentially

contaminated with chemical agent from operations involving agent. These waste streams include spent chemical neutralization solution, spent activated carbon, DPE suits and other protective gear, and wooden pallets. Several minor waste streams also are produced, such as spill cleanup materials, waste hydraulic fluid, waste oil, used equipment and tools, and trash. These other waste streams are briefly described as follows:

- *Spent Chemical Neutralization Solution.* This waste is generated from the decontamination of equipment, contaminated DPE suits, and any chemical agent spills. These wastes are typically generated in the demilitarization process buildings in which operations involving chemical agents are performed. Spent neutralization solution flows through floor drains and is collected in sumps located under the munitions demilitarization building (MDB). The collected spent neutralization solution is then pumped to spent neutralization solution tanks prior to use as a coolant in the secondary chamber of the LIC.
- *Spent Activated Carbon.* The primary source of spent activated carbon is the heating, ventilation, and air conditioning (HVAC) filter system of the demilitarization buildings. In the MDB, activated carbon is used to filter out chemical agent vapors in exhaust air and is periodically replaced either when agent is detected above a specified level between filter banks or based on a specified schedule. Smaller amounts of carbon are used in chemical agent tank filters, Automatic Continuous Air Monitoring System (ACAMS) filters, and in respirator canisters.
- *DPE Suits.* DPE suits are used as protective equipment by personnel working in specific areas of the demilitarization plant. These suits could potentially be exposed to vapor and liquid chemical agents during operations. DPE suits that have been exposed to liquid agent or agent vapors are decontaminated as part of the exit procedures followed by personnel leaving a contaminated area. All DPE suits (whether or not they were contaminated) are classified as waste after a single use. Other protective material generated as waste includes toxicological agent protective (TAP) gear made of butyl rubber. TAP gear is designed for reuse, but it is discarded when considered contaminated or otherwise unfit for use. Although DPE suits can be effectively incinerated, CAMDS is in the process of evaluating thermal desorption as a treatment alternative for this waste stream.

- *Wooden Pallets.* Wooden pallets are used for packaging and storing munitions. These pallets are classified as waste when the munitions are removed for processing. Pallets potentially can be contaminated with chemical agent from leaking munitions or when a chemical agent is spilled. At this point, they would be classified as hazardous waste.

2.2.3 Chemical Agent Munitions Disposal System (CAMDS)

2.2.3.1 Process Description

CAMDS has been in operation since 1979, conducting research, development, and demonstration of various methods of demilitarizing chemical munitions and treating the wastes resulting from demilitarization processes. The chemical agents investigated by CAMDS are the nerve agents GA, GB, and VX, and the blister agents H/HD, HT, and L. The current mission of CAMDS is to provide continuing process development and demonstration of integrated munitions demilitarization and waste treatment plants and processes.

CAMDS operates as a pilot TSDF to demonstrate and refine baseline and alternative technologies for treatment of chemical agents and associated wastes. The general areas described are munitions handling and disassembly, incineration of wastes resulting from munitions handling, pollution abatement systems associated with incineration and munitions handling, and treatment of wastes such as scrap metal, brines, and ash to minimize the amount of waste requiring disposal. Information generated aids in the technical and economic feasibility evaluation of munitions handling equipment, incinerators, pollution abatement systems, and alternative treatment methods. CAMDS waste treatment units consist of fabricated equipment reflecting state-of-the-art technology.

The units at CAMDS are sized to handle actual munitions at rates that demonstrate the processes involved. The equipment and process control technologies provide reliability data for demilitarization of chemical munitions, extended operations maintenance evaluation, incineration of actual munitions components and chemical agents, control of integrated processes, and treatment of flue gases and solid residues.

DCD's entire stockpile of lewisite, 10 ton containers, will be destroyed at CAMDS through a neutralization process originally developed in 1991 by Chem-Security Ltd. to destroy the Canadian stockpile of lewisite. Lewisite is converted to sodium arsenate in a three-step batch process. CAMDS has already received a

RCRA RD&D permit for this process, with operation scheduled to begin in early 1999. Because of the presence of arsenic in this waste stream, stabilization is proposed as a specified LDR treatment technology for process residue.

2.2.3.2 CAMDS Waste Streams

Table 2.4 lists the chemical agent related waste streams that are generated at the CAMDS and includes information pertaining to incineration of each waste stream.

2.2.4 Dugway Proving Ground (DPG)

2.2.4.1 Process Description

DPG generates chemical agent related waste in fulfilling its mission of developing and testing attack deterrent capabilities, developing and testing methods to protect personnel and equipment from chemical agent attacks, and determining the effects of chemical warfare agents and neutralization solutions on military equipment and supplies. The majority of the chemical agent related waste is generated following chemical neutralization of materials involved in chemical agent testing. Since testing spent neutralization fluid is part of the test activities at DPG, the material is not considered to be waste until after testing is completed. The remaining chemical agent related wastes that may be generated at DPG include range-recovered munitions, personal protective equipment, and spilled material and cleanup waste.

2.2.4.2 Waste Streams

In addition to the "P" and "U" listed chemicals that become wastes, Table 2.5 lists the chemical agent related waste streams that are generated at DPG. The wastes generated by DPG are not currently treated by incineration; however, all the streams generated are amenable to incineration.

2.3 WASTE CHARACTERIZATION

Section 1.2 provided a discussion of the chemicals of concern and the chemical agent associated waste streams. As indicated in Table 1.1, the

TABLE 2.4 CAMDS Waste Streams

Waste Stream	Waste No.	Currently Treated by Incineration?
"P" listed waste chemicals	P901-P910	Yes, except for lewisite
Brine reduction area	K908	No. Off-site TSDF
baghouse residue		
Brine salts	K908	No. Off-site TSDF
Neutralization fluid	K901	Yes.
Deactivation furnace system	K906	No. Off-site TSDF
(DFS) cyclone residue		
DFS heated discharge conveyor	K906	No. Off-site TSDF
(HDC) ash		
DFS refractory	K907	No. Off-site TSDF
Demilitarization protective	K903	No. Permitted on-site storage
ensemble (DPE) suits		
Laboratory liquid wastes	K901,	No. Permitted on-site storage
	K904	
Laboratory solid wastes	K902,	No. Permitted on-site storage
	K903	
Miscellaneous metal parts	K902	No. Off-site TSDF
Mist eliminator filter/demister	K902,	No. Off-site TSDF
candles	K903	
Metal parts furnace (MPF) ash	K906	No. Off-site TSDF
MPF metal	K902	No. Off-site TSDF
MPF refractory	K907	No. Off-site TSDF
MPF residue	K902,	No. Off-site TSDF
	K903	
Pollution abatement system	K908	No. Permitted on-site storage
(PAS) brine		
PAS brine sump sludge	K908	No. Off-site TSDF
Plastics	K903	No. Off-site TSDF
Soil	K903	No. Off-site TSDF
Spent activated carbon	K905	No. Permitted on-site storage
Spent hydraulic fluid	K904	Yes.
Spent silver fluoride pads	K903	No. Off-site TSDF
Spill cleanup material	K903	No. Off-site TSDF
Styrofoam	K903	No. Off-site TSDF
Trash, debris, and protective	K903	No. Off-site TSDF
clothing		
Waste oil	K904	No. Off-site TSDF
Wooden pallets	K903	No. Off-site TSDF

TABLE 2.5 DPG Waste Streams

Waste Stream	Waste No.	Currently Treated by Incineration?
"P" and "U" listed waste chemicals	P901-P910, U901-U902	No.
Neutralization fluid	K901	No. Off-site TSDF
Laboratory liquid wastes	K901, K904	No. Off-site TSDF
Laboratory solid wastes	K902, K903	No. Off-site TSDF
Miscellaneous metal parts	K902	No. Off-site TSDF
Plastics	K903	No. Off-site TSDF
Soil	K903	No. Off-site TSDF
Spent activated carbon	K905	No. Permitted on-site storage
Spent silver fluoride pads	K903	No. Off-site TSDF
Spill cleanup material	K903	No. Off-site TSDF
Styrofoam	K903	No. Off-site TSDF
Trash, debris, and protective clothing	K903	No. Off-site TSDF
Water/groundwater	K904	No. Permitted on-site storage

hazardous constituents of concern are the chemical agents themselves and associated chemicals, such as degradation products (e.g., EA2192, a degradation product of VX).

Neat agents, such as GB, HD, and VX, contained in stockpile munitions have a purity ranging from approximately 27 to 99% by weight (TOCDF 1997). Concentrations of agents in spent neutralization solutions, aqueous laboratory wastes, and scrubber brine are generally below 20 parts per billion (ppb) for VX and GB, or 200 ppb for HD.

The solid waste materials are generally classified according to the U.S. Army's decontamination standards [Department of the Army Pamphlet (DA PAM) 385-61 (DA undated)] of 1X, 3X, or 5X. These standards were developed for worker safety purposes and have been used by the Army as a general waste-management tool to ensure safe management of wastes. The decontamination category X codes can be applied either by actual monitoring or based on knowledge of an item's degree of decontamination. The vapor concentration limits used in the 1X, 3X, and 5X standards are the airborne exposure limits (AELs) for either unmasked agent workers or nonagent workers and the general population. The following DA Pam 385-61 definitions are for Army use and are given here for reference and purposes of clarification:

- **1X Designation.** Wastes are designated 1X when they are suspected or known to have chemical agent contamination. If

chemical agent vapor monitoring (of confined ventilation space) results in values exceeding 0.0001 milligram per cubic meter (mg/m^3) for GB, 0.003 mg/m^3 for HD, or 0.00001 mg/m^3 for VX, the waste is designated as 1X. These vapor limits are the 8-hour time-weighted average (TWA) for unmasked agent worker AELs (DA PAM 385-61). 1X wastes must be maintained under direct U.S. Army control.

- 3X Designation.** Wastes with, at most, trace quantities of chemical agent contamination and that can be safely handled by workers without the use of respiratory protection are designated as 3X. When chemical agent vapor concentrations measured in a confined ventilation space, such as a plastic bag or a container, are below either 0.0001 mg/m^3 for GB, 0.003 mg/m^3 for HD, or 0.00001 mg/m^3 for VX, the item is considered to be 3X. Items and materials determined to be 3X are maintained under government control and are not released to the public for unrestricted use. The 3X category applies to items of simple shape (no crevices, threads, etc.), made of essentially impervious materials (glass, steel, etc.), that have been disassembled and surface decontaminated. If an item is of complex shape (e.g., has threads or intricate folds) or is made of permeable material (e.g., plastic or cloth), then it must be monitored to determine whether the 3X designation is applicable (DA PAM 385-61). 3X wastes may be sent off-site to commercial TSDFs for further management. Since TSDFs operate under government-issued permits, wastes sent there are considered to be under government control.
- 5X Designation.** Materials that have undergone thermal treatment at temperatures above 538°C (1,000°F) for a period of at least 15 minutes are designated 5X. 5X materials are allowed by the Army to be released for unrestricted disposal, recycling, or reuse. Thermal treatment at temperatures above 538°C (1,000°F) for a period of at least 15 minutes have been shown to destroy chemical agent below the vapor standard (72-hour general population limit) of 0.0001 mg/m^3 for HD, and 0.000003 mg/m^3 for GB and VX for material of simple design and impermeable construction (CAMDS 1996). The exact conditions for thermal treatment may vary for other materials. This process is considered to meet the definition of incineration.

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3 SUPPORT FOR INCINERATION OF CHEMICAL AGENT WASTE STREAMS AS APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGY

The purpose of this section is to support incineration as an applicable LDR treatment technology on the basis of capability. To be considered a specified LDR technology, a technology must be capable of treating either the waste in question or a waste that is similar in terms of the parameters that affect the selection of the treatment method, such that LDR concentration-based standards are achieved. Parameters that affect incineration performance may include physical and chemical characteristics, bond disassociation energy, thermal conductivity, inorganic and organic composition, and concentration of the constituents of concern.

3.1 APPLICABILITY OF INCINERATION AS A TREATMENT TECHNOLOGY

Incineration is a controlled high-temperature oxidation process that converts the principal elements in most organic compounds (carbon, oxygen, and hydrogen) to CO_2 and H_2O . The toxic or hazardous nature of an organic compound is usually a result of the structure of the molecule rather than the elements it contains. Therefore, destruction of the molecular structure usually eliminates the toxic or hazardous properties. Combustion of organic phosphorous compounds, which includes the nerve agents, also produces P_2O_5 under most conditions. Sulfur containing compounds, such as mustard, will produce SO_2 upon complete combustion. The halogens in chemical agents, chlorine and fluorine, will form into HCl and HF . Chemical agents and chemical agents contained within chemical agent associated "K" wastes can be readily destroyed by incineration. The composition of the flue gas when incinerating the chemical agents GB, VX, and H, which are by far the major components of the stockpile, is shown in Table 3.1.

The chemical agent associated waste streams that are considered suitable for incineration treatment are discussed Section 1.2. The waste streams include most of the agents that become wastes (the parent agent), the "P" (P901-P910) listed wastes, and

TABLE 3.1 Composition (volume percent) of Flue Gas when Incinerating Chemical Agents^a

Component	GB	VX	H
CO_2	5.13	4.83	5.36
H_2O	5.67	5.51	4.88
N_2	76.16	76.76	76.01
O_2	12.08	12.23	11.73
HCl			1.34
HF	0.65		
SO_2		0.27	0.68
P_2O_5	0.31	0.13	
NO_2		0.27	
Total	100.00	100.00	100.00

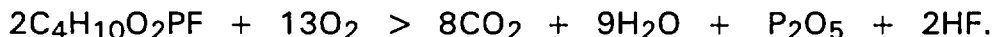
^a Note: Temperature of incineration is 2,100°F.

Source: Holmes & Narver (1982).

specific chemical agent associated wastes (typically, wastes that result from treatment of the parent agent), the "K" listed wastes (K901-K908). These waste streams are identified as hazardous because of their hazardous constituent content. The hazardous constituents in the proposed listed wastes can be divided into four groups: the nerve agents, the mustards, arsenicals, and others. The capability of incineration as a treatment technology to destroy chemical agents to the proposed LDR concentration-based treatment standards for each group is presented below.

3.2 INCINERATION OF NERVE AGENTS AND RELATED COMPOUNDS

The nerve agents include the family of G agents (GA, GB, GD, and GF), the V agents (VX and Vx) and the V agent hydrolysis products (EA2192). The chemical structures of these compounds are shown in Appendix A. The majority of the data developed are on the incineration of GB and VX. The oxidation reactions for these agents, shown below, are similar and are basically the same for all the other compounds in this group. The oxidation of GB proceeds as follows:



The products of oxidation of GD and GF are the same as GB, while GA will produce some NO_2 in addition to the other products.

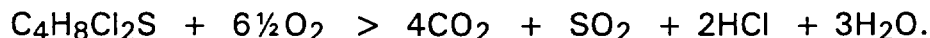
The oxidation of VX proceeds as:



The products of oxidation of Vx and EA2192 are expected to be essentially the same as VX.

3.3 INCINERATION OF MUSTARD AND RELATED COMPOUNDS

Included in the mustard family are H, HD, HN1, HN3, HT, HQ, Q, and T. The chemical structures of these compounds are shown in Appendix A. The majority of the data developed are on the incineration of HD. The oxidation reaction for HD is basically the same as for the other compounds and is as follows:



The products of oxidation of H, HT, HQ, Q, and T are expected to be essentially the same as HD, while HN1 and HN3 will produce NO₂ in place of SO₂.

3.4 INCINERATION OF ARSENICALS

The arsenical group consists of lewisite 1 (including lewisite 2 and 3) and the mixture HL. Lewisite oxide is a hydrolysis product and is formed rapidly when lewisite 1 is exposed to water or water vapor. All of these compounds contain arsenic, which is a hazardous constituent that is not destroyed by incineration. Although lewisite can be incinerated to meet the LDR concentration-based standards, the Army is not proposing incineration as a treatment technology for arsenicals. However, with respect to organometallic constituents in contaminated media, EPA has recognized that the situation may call for two or more treatment technology trains (e.g. one treatment for organics, which could be incineration, and another for metals, either extraction or chemical stabilization) to achieve the treatment standards. [Federal Register, Vol. 63, No. 100 (63 FR 100), May 26, 1998)]

Incineration of lewisite would result in oxidizing the organic moiety to CO₂, HCl, and H₂O, while the arsenic would be converted to the oxide. Treatment of the metal constituent in the generated waste stream, if above RCRA toxicity characteristics standards, would then be either by chemical extraction or stabilization, which are EPA demonstrated LDR treatment technologies.

Although lewisite could be incinerated to meet LDR concentration-based standards, the Army intends instead to apply a chemical neutralization technology, as indicated previously. The Army intends, following chemical neutralization, to treat the spent neutralization fluid, which contains sodium arsenate, with a stabilization technology. Stabilization is therefore proposed as the specified LDR treatment technology for this waste stream. If the spent neutralization fluid exceeds EPA's toxicity characteristic standards for arsenic, EPA's LDR standards for arsenic would also apply.

3.5 INCINERATION OF OTHER CHEMICALS OF CONCERN

CK, CG, HF, and chloroform have been listed by the EPA, and DSHW is deferring to EPA's promulgated LDR treatment standards for these hazardous constituents. Only limited data are available on the incineration of DM (U901) and BZ (U902), therefore incineration is not proposed as a LDR treatment technology for these chemical agents or associated wastes.

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4 PERFORMANCE DATABASE FOR INCINERATION

This section presents the technical data that support the use of incineration as a specific LDR technology under the proposed UCAR. The data presented demonstrate that incineration is a proven technology capable of satisfying the primary criterion of reducing the concentration of chemical agents in waste matrices to below the proposed LDR concentration-based standards. As a technology, incineration is effective for treatment of wastes with similar chemical and physical properties (EPA 1988a-b).

Another important consideration for demonstration/qualification of incineration as a specified LDR treatment technology for chemical agent and associated wastes is that incineration has been permitted by Utah for use at TOCDF and has been employed in full-scale operation for waste treatment at JACADS, as well as TOCDF and CAMDS (EPA 1988a-b). Incineration is evaluated in this section as a demonstrated technology on the basis of a review of current demilitarization operations, as well as industrial practice.

4.1 CHEMICAL AGENTS

4.1.1 Waste Description

The chemical agent waste group consists of liquid agent drained from munitions and bulk containers. The agents would be designated with the proposed chemical agent specific "P" (P901-P910) waste codes. For CAMDS and TOCDF, the chemical agents of concern are GB (P901), HD (P904), VX (P903), and potentially GA (P902) and HT (P910). Incineration of neat chemical agents that have an arsenic component [e.g. L (P905), DM (U901)] is not planned by the Army, as discussed earlier.

4.1.2 Applicability

Incineration has been successfully practiced for the full-scale treatment of liquid GB, HD, and VX. As of February 7, 1999, JACADS had destroyed 1,704 tons of GB, HD, and VX, and TOCDF had destroyed 2,556 tons of GB.

4.1.3 Demonstration

Incineration is considered demonstrated for destruction of chemical agent on the basis of the Army's more than 20 years of experience with the use of incineration in chemical demilitarization. In 1982, the Army selected incineration as the preferred treatment method for chemical demilitarization. In 1984, the National Research Council's (NRC's) Committee on Review and Evaluation of the Army Stockpile Disposal Program evaluated possible disposal technologies and endorsed incineration as being a safe and effective disposal method (NRC 1984).

As part of an extensive effort to demonstrate incineration as a successful technology for demilitarization, operational verification testing (OVT) of the incineration process was conducted from July 1990 through March 1993 at JACADS. During the OVT activities, RCRA-mandated trial burns were conducted for the LIC, MPF, and DFS to demonstrate that munitions containing GB, HD, and VX can be destroyed while protecting human health and the environment. The NRC's Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program evaluated the results of the OVTs, endorsed incineration for the disposal of the chemical stockpile, and recommended the initiation of systemization of TOCDF (NRC 1994).

At JACADS, trial burns have been successfully completed to verify the performance of the LIC, DFS, and MPF. Qualitative and quantitative results of the trial burns are provided herein. For the LIC, RCRA trial burn data were collected from incinerator runs for the destruction of the three chemical agents in the LIC: GB, HD, and VX [United Engineers and Constructors (UEC) 1993; Southern Research Institute (SRI) 1991, 1992a]. The trial burns consisted of individual incinerator runs conducted with liquid chemical agent and spent neutralization solution as the feed material. Simulated neutralization solution was used in the GB trial burn. During the runs, the LIC performance was evaluated against RCRA-specified performance criteria, including destruction and removal efficiency (DRE) of the principal organic hazardous constituents (POHC) and the emission from the exhaust stack of particulate matter, carbon monoxide, and acid gas. In addition, the characteristics of the combustion residue and various parameters relating to furnace operation were monitored. For JACADS, the requirements were as follows:

- The DRE of chemical agent must be 99.99% or greater, and the chemical agent concentration in the stack must be below the allowable stack concentration (ASC) (0.0003 mg/m^3 for GB and VX, and 0.03 mg/m^3 for HD).

- Particulate emissions from the exhaust stack must not exceed 180 milligrams per dry standard cubic meter (mg/dsm³) when corrected to 7% oxygen content in the exhaust gas on a dry basis.
- The average hourly combustion efficiency must be greater than 99% and the carbon monoxide concentration must not exceed a rolling hourly average of 100 ppm or a 5 minute peak of 200 ppm (both values corrected to 7% oxygen on a dry basis) in the exhaust gas.
- The removal of hydrogen chloride from the exhaust gas must be 99% or greater, or the hydrogen chloride emission rate must be less than 4 pounds per hour.

Other requirements for the JACADS trial burns included monitoring oxygen, carbon dioxide, volatile and semivolatile products of incomplete combustion (PICs), polychlorinated dibenzo-p-dioxins and dibenzofurans, metals, and hydrocarbons in the stack gas. Additionally, volatile and semivolatile PICs, dioxins, and furans; soluble chloride; fluoride; phosphate; and pH were analyzed in the liquid process residuals.

The analytical data from emissions testing verified the destruction of VX in the LIC (SRI 1992a). Stack emissions of VX were not detected during the VX LIC trial burn. The stack was monitored both in the stack house and in the blower duct. The limit of quantitation (LOQ) of the ACAMS, which were used to monitor agents, was less than one-fifth of the ASC (0.0003 mg/m³). Thus, VX was not detected above the LOQ for VX, which was 0.00006 mg/m³. The DRE for VX in each of the individual test runs was greater than 99.9999997%, thus exceeding the requirement for at least 99.99%. The measured particulate matter emission levels were well below the established particulate limits. Hydrogen chloride also was not detected above the detection limit of 0.03 pounds per hour and also met the requirement. Combustion efficiencies based on carbon monoxide concentrations exceeded the requirement of 99.9% in all cases. During the trial burns, the primary and secondary chamber exhaust temperatures were maintained within the range specified in the approved trial burn plan.

Similar results were obtained from the GB (SRI 1991) and HD (UEC 1993) trial burns. The DRE for GB exceeded 99.999998% in all three incinerator runs. The DRE for HD ranged from greater than 99.999953% to greater than 99.999975%. Other emission rates, such as particulate matter and hydrogen chloride, and the combustion efficiencies were all well below the corresponding requirements.

In addition to chemical agent analysis in the stack gas, the scrubber brine and scrubber liquor were also analyzed for agent, as well as the required inorganic and organic constituents. Chemical agent was not detected in these streams at levels above 20 ppb for HD or 200 ppb for GB and VX. Except for concentrations of chromium and lead, process samples were within regulatory limits for all parameters tested. Volatile and semivolatile PICs detected were related to the fuel used in the furnace (fuel oil at JACADS) and were concluded to be consistent with other combustion operations using the same fuel. No significant agent degradation products were found among the PICs from the LIC trial burns. No dioxins and furans were detected in the stack at levels significantly above those associated with the blank samples. Dioxins and furans detected were at levels approaching the quantitation limits. Metal emission rates were also below the corresponding guidance limits at the time of the trial burns.

Tables 4.1, 4.2, and 4.3 summarize the results of the RCRA trial burns conducted at JACADS for the chemical agents HD, VX, and GB, respectively. These tables summarize emissions data, values of key operating parameters, and results of the analysis of process streams (residuals).

4.1.4 Conclusion

In 1984, at the time of the decision on selection of a treatment technology for the chemical stockpile, incineration was the Army's preferred method of mustard agent disposal. Incineration was considered superior to other treatment technologies as a complete destruction method for all components of the stockpile and was selected as the technology to achieve that goal.

The results of the JACADS trial burns described above and the operational experience on the use of incineration from the early 1990s at JACADS and the current operation of TOCDF support the selection of incineration as a demonstrated LDR technology for HD, VX, and GB.

On the basis of the physical and chemical properties of other chemical agents and other data on incineration, it can be inferred that incineration would be suitable for treating other chemical agents and hazardous constituents with exceptions noted previously [e.g., DM (U901) and BZ (U902)] to meet proposed LDR concentration-based standards. Clearly since incineration has been successfully used at JACADS, it is considered to be a demonstrated technology for the treatment of GB, HD, and VX.

TABLE 4.7 Summary Data for DUN Incineration of GB-Contaminated Dunnage at JACADS^a

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Requirement
Emissions Data						
GB emissions ^b	mg/m ³	<0.00006	<0.00006	<0.00006	<0.00006	<0.0003
DRE – GB	%	>99.9999868	>99.9999868	>99.9999868	>99.9999868	≥99.99
Oxygen ^c	%	10.9	11.2	11.3	11.4	8-14
Carbon dioxide ^c	%	7.6	7.5	7.3	7.2	
Carbon monoxide ^d	ppm	34.5	42.5	42.9	40.1	<100 hourly average
Combustion efficiency	%	99.95	99.94	99.94	99.94	
Particulate matter corrected to 7% O ₂ ^e	mg/dsm ³	4.20	3.53	3.06	16.00	>180
HCl emissions	lb/h	0.59	0.63	0.68	0.72	<4
Operating Data						
Agent feed rate	lb/h	10.3	10.3	10.3	10.3	NA
Primary chamber max/min	°F	1,377/1,899	1,401/1,905	1,351/1,968	1,387/1,956	NA
After-burner max/min	°F	1,895/2,141	1,900/2,043	1,884/2,043	1,881/2,043	NA
Process Stream Data						
Combustion chamber ash	ppb	<20	<20	<20	<20	NA
Baghouse ash	ppb	<20	<20	<20	<20	NA
Quench tower recirculation Line	ppb	<20	<20	<20	<20	NA

^a Notation:

DRE = destruction and removal efficiency
DUN = dunnage incinerator
lb/h = pounds per hour
mg/dsm³ = milligram per dry standard cubic meter
mg/m³ = milligram per cubic meter
NA = not available
ppb = parts per billion
ppm = parts per million.

^b Since GB was not detected in the emissions, table values represent the lower limit of quantification of the sampling and analysis methods used.

^c ORSAT analysis values.

^d Corrected to 7 percent O₂ on a dry basis.

^e Average of the Method 5 acid train and Method 5 multiple metals train results.

Source: Raytheon, 1995.

TABLE 4.6 Summary Data for DFS Incineration of VX Rockets at JACADS^a

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Requirement
Emissions Data						
VX emissions ^b	mg/m ³	<0.000054	<0.000063	<0.000057	<0.000078	<0.0003
DRE – VX	%	NA ^c	NA	NA	NA	
Oxygen ^d	%	13.9	13.0	13.2	13.1	
Carbon dioxide ^d	%	5.6	6.1	5.7	6.1	
Carbon monoxide	ppm	30	26.2	20.4	34.5	< 100
Combustion efficiency	%	99.95	99.96	99.96	99.94	
Particulate matter corrected to 7% O ₂ ^e	mg/dsm ³	1.10	4.55	4.38	1.51	< 180
HCl emissions	lb/h	NA ^f	NA	NA	NA	< 4
Operating Data						
Agent feed rage	lb/h	5.6	6.9	6.5	4.9	NA
Primary chamber	°F	1,050	1,049	1,050	1,051	NA
After-burner	°F	2,006	1,998	1,998	1,998	NA
Process Stream Data						
Scrubber brine	ppb	< 20	< 20	< 20	< 20	NA
Scrubber liquor	ppb	< 20	< 20	< 20	< 20	NA
Heated discharge conveyor ash	ppb	< 20	< 20	< 20	< 20	NA
Cyclone residue	ppb	< 20	< 20	< 20	< 20	NA

^a Notation:

DFS = deactivation furnace system
DRE = destruction and removal efficiency
lb/h = pounds per hour
mg/dsm³ = milligram per dry standard cubic meter
mg/m³ = milligram per cubic meter
NA = not available
ppb = parts per billion
ppm = parts per million.

^b Since VX was not detected in the emissions, table values represent the lower limit of quantification for the sampling and analysis methods used.

^c The DRE for VX was not calculated because it was not a requirement of the test.

^d ORSAT analysis data.

^e Average of the Method 5 acid train and Method 5 multiple metals train results.

^f Not calculated because no HCl was detected.

Source: Southern Research Institute (1992a).

TABLE 4.5 Summary Data for DFS Incineration of GB Rockets at TOCDF^a

Parameter	Units	Run 1	Run 3 ^b	Run 4	Requirement
Emissions Data					
GB emission ^c	mg/m ³	<0.00000608	<0.0000118	<0.00000365	<0.0003
DRE – GB	%	>99.9999936	>99.999986	>99.9999953	≥99.99
Oxygen	%	9.0	9.5	9.6	
Carbon dioxide	%	6.5	7.0	6.9	
Carbon monoxide corrected to 7% O ₂	Ppm	8	7	7	<100
Combustion efficiency	%	99.99	99.99	99.99	>99.9
Particulate matter corrected to 7% O ₂	lb/h	0.36	0.12	0.35	≤48.3
HCl emissions	lb/h	<0.04	<0.04	<0.04	≤4
Operating Data					
GB feed rate	lb/h	13	11	9.7	NA
Quench exhaust gas	°F	1,450	1,476	1,450	NA
HDC bottom	°F	1,072	1,089	1,079	NA
HDC top	°F	1,092	1,097	1,096	NA
After-burner	°F	2,151	2,150	2,149	NA
Process Stream Data					
Scrubber brine	ppb	<20	<20	<20	N/A
Stack condensate	ppb	<20	<20	<20	N/A
Heated discharge conveyor ash	ppb	<20	<20	<20	N/A
Cyclone residue	ppb	<20	<20	<20	N/A

^a Notation:

DFS = deactivation furnace system
DRE = destruction and removal efficiency
HDC = heated discharge conveyor
lb/h = pounds per hour
mg/m³ = milligram per cubic meter
NA = not available
ppb = parts per billion
ppm = parts per million.

^b The results of run 2 were not reported because of difficulties maintaining proper sampling temperatures in two of the sample trains.

^c Since GB was not detected in the emissions, table values represent the lower limit of quantification of the sampling and analysis methods used.

Source: Edgerton, Germehausen, and Grier (1997).

4.2 SPENT NEUTRALIZATION SOLUTION – K901

4.2.1 Waste Description

With the exception of the RRS, MMD, and lewisite-associated spent neutralization fluids, the agent associated spent neutralization fluids meet LDR treatment standards as generated. Spent neutralization solution wastes are those solutions used to neutralize one or more of the hazardous constituents proposed to be added to the list of hazardous constituents. Background Document I, "Chemical Neutralization as a Land Disposal Restriction Treatment Technology for Chemical Agent Associated Waste," supports chemical neutralization as a treatment technology for specific agent associated waste streams.

4.2.2 Applicability

With the exception of the RRS, MMD, and lewisite-associated spent neutralization fluids, the waste stream residuals generated by chemical neutralization meet LDR treatment standards as generated. The Army in some of its chemical demilitarization process operations has elected to reuse spent neutralization solutions to cool incinerator gas (e.g., in the secondary chamber of the LIC at TOCDF). For example, the TOCDF RCRA permit specifies that spent neutralization solution will be treated by incineration in the secondary chamber of the LIC. It is reused as a coolant as the gas from the primary chamber enters the secondary chamber, and is incinerated in the process.

4.2.3 Demonstration

RRS- and MMD-associated spent neutralization fluids are intended to be incinerated, and incineration is proposed as the LDR treatment technology for these waste streams. As indicated above, spent neutralization solutions are treated in the secondary chambers of the LIC at TOCDF and JACADS.

4.2.4 Conclusion

The spent neutralization solution waste stream K901 meets LDR treatment standards as generated; therefore, incineration is not required. The exceptions to this are the MMD and RRS spent neutralization fluids, which will be incinerated as an LDR technology. The trial burn data collected during the incineration of chemical

agent in the LIC, along with spent neutralization fluid, support the destruction of any residual chemical agent in the spent neutralization solution. On the basis of the DRE obtained for the trial burn principal organic hazardous constituents (POHCs), other organics present in the neutralization solution or other aqueous wastes that have similar or higher incinerability rankings also are expected to be destroyed to similar levels. Therefore, incineration is considered an applicable and demonstrated LDR technology for treatment of RRS and MMD spent neutralization fluids.

4.3 NONPERMEABLE SOLID MATERIALS – K902

4.3.1 Waste Description

Nonpermeable solids are designated with the waste code K902 and may have chemical agent contamination on their exterior surfaces. The wastes in this treatability group consist primarily of agent wetted metal parts from equipment and tools used in the maintenance of equipment and machinery and other nonpermeable solid items, such as ceramics and glass. These items are typically chemically neutralized to remove surface agent contamination, and if neutralization is applied, the LDR treatment standard is met. If not chemically neutralized, the wetted areas may contain hazardous constituents and may be incinerated to meet LDR treatment standards.

4.3.2 Applicability

Incineration is considered an applicable LDR treatment method for metal parts and other nonpermeable solids (such as ceramics and glass) contaminated with chemical agent. Incineration is applicable because it produces conditions of high temperature that destroy hazardous organic compounds and, in particular, chemical agents.

4.3.3 Demonstration

Incineration has been used in full-scale operations at TOCDF and JACADS to destroy chemical agents on drained munitions and bulk containers with internal surfaces that have been wetted with agent. Chemical agent contaminated metal equipment and tools have been approved for incineration in the MPF at TOCDF. Furthermore, several agent contaminated bulk solid wastes are approved inputs for incineration in the JACADS MPF; these include metal containers, metal overpacks,

tools, metal hardware, metal equipment (such as pumps, pipes, valves, etc.), metal instruments, metal laboratory equipment components, and glass. The MPF is currently used to treat munition bodies and empty ton containers. The DFS is used to decontaminate chemical agent contaminated rocket parts along with the associated energetic materials.

Incineration also is considered demonstrated on the basis of the results of the MPF and DFS trial burns conducted at JACADS and TOCDF [UEC 1992; SRI 1992b; Edgerton, Germehausen, and Grier (EG&G) 1997]. Analytical data from emissions testing verified the destruction of chemical agent during the incineration of HD ton containers in the MPF, and VX and GB rockets in the DFS. Stack emissions of agents HD, VX, and GB were below detection limits. At TOCDF, GB emissions were below 0.0000118 mg/m³. The calculated DRE for chemical agent in these trial burns exceeded 99.9999%. The measured particulate matter and hydrogen chloride emissions were well below RCRA limits. Combustion efficiencies based on carbon monoxide concentrations exceeded the requirement of 99.9% in all cases. Chemical agent was not detected in the HDC ash and the cyclone residue, which are the solid residues from the processing of rockets in the DFS.

The results of the MPF RCRA trial burn conducted at JACADS for incineration of ton containers contaminated with HD are presented in Table 4.4. Results of incineration of GB-contaminated drained rockets in the DFS trial burns at TOCDF and of VX-contaminated drained rockets at JACADS are summarized in Tables 4.5 and 4.6. In each case, the DRE for chemical agents was at least 99.999%. Agent was not detected in the stack emissions in any of the tests.

4.3.4 Conclusion

Incineration is considered applicable and demonstrated for contaminated nonpermeable solid materials. It has been used successfully in full-scale operations at TOCDF and JACADS to destroy GB, VX, and HD on solid wastes to levels below proposed LDR concentration-based standards. Incineration is an applicable and demonstrated technology for treatment of chemical agent nonpermeable solid wastes to meet proposed LDR concentration-based standards.

TABLE 4.4 Summary Data for MPF Incineration of HD Ton Containers at JACADS*

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Requirement
Emissions Data						
HD emission ^b	mg/m ³	<0.0054	<0.0066	<0.0069	<0.0066	<0.03
DRE – HD	%	≥99.9996	≥99.9997	≥99.9997	≥99.9997	≥99.99
Oxygen ^c	%	14.5	14.8	14.5	14.2	
Carbon dioxide ^c	%	4.6	4.3	4.5	4.9	
Carbon monoxide corrected to 7% O ₂	ppm	13	12.7	2.0	2.1	≤100 hourly average
Combustion efficiency	%	99.97	99.97	>99.99	>99.99	
Particulate matter ^d corrected to 7% O ₂	mg/dsm ³	10.92	2.68	3.13	0.89	≤180
HCl emissions	lb/h	<0.00326	0.0497	<0.00277	<0.00328	≤4
Operating Data						
HD feed rate	lb/container	12.8	51.8	58.4	60.3	NA
Primary chamber						
Zone 1	°F	1,408	1,425	1,418	1,457	NA
Zone 2	°F	1,456	1,453	1,460	1,461	NA
Zone 3	°F	1,459	1,449	1,449	1,451	NA
After-burner	°F	2,003	2,003	2,003	1,998	NA
Process Stream Data						
Scrubber brine	ppb	<200	<200	<200	<200	N/A
Scrubber liquor	ppb	<200	<200	<200	<200	N/A
Stack condensate	ppb	<200	<200	<200	<200	N/A
Residue/ash	ppb	<200	<200	<200	<200	N/A

* Notation:

DRE = destruction and removal efficiency
lb/h = pounds per hour
mg/dsm³ = milligram per dry standard cubic meter
mg/m³ = milligram per cubic meter
MPF = metal parts furnace
NA = not available.
ppb = parts per billion
ppm = parts per million.

^b Since HD was not detected in the emissions, table values represent the lower limit of quantification of the sampling and analysis methods used.

^c ORSAT analysis data.

^d Average of the Method 5 acid train and Method 5 multiple metals train results.

Source: United Engineers and Constructors (1992).

TABLE 4.3 Summary Data for Incineration of GB in the Liquid Incinerator at JACADS^{a,b}

Parameter	Units	Run 1	Run 2	Run 3	Requirement
Emissions Data					
GB emissions ^c	mg/m ³	<0.000057	<0.000063	<0.000063	<0.0003
DRE – GB	%	<99.999998	<99.999998	<99.999998	<99.99
Oxygen ^d	%	14.6	14.4	14.6	
Carbon dioxide ^d	%	4.5	4.6	4.5	
Carbon monoxide corrected to 7% O ₂	ppm	19	26	18	≤100 hourly average
Combustion efficiency	%	99.96	99.94	99.96	>99.9
Particulate matter corrected to 7% O ₂	mg/m ³	3.7	4.2	3.9	<180
HCl Emissions	lb/h	≤0.0023	≤0.035	≤0.013	<4
Operating Data					
Agent feed rate	lb/h	750	750	750	NA
Primary chamber	°F	2,701	2,701	2,696	NA
After-burner	°F	2,001	2,000	1,998	NA
Process Stream Data					
Scrubber brine	ppb	<20	<20	<20	NA
Scrubber liquor	ppb	<20	<20	<20	NA
Salt residue in furnace	ppb	<20 ^e	-	-	NA

^a Notation

DRE = destruction and removal efficiency
 lb/h = pounds per hour
 mg/m³ = milligram per cubic meter
 NA = not available.
 ppb = parts per billion
 ppm = parts per million.

Source: Southern Research Institute (1991).

^b Water was used in this trial burn rather than spent neutralization solution.

^c Since GB was not detected in the emissions, table values represent the lower limit of quantification of the sampling and analysis methods used.

^d ORSAT analysis values.

^e Sampled once at end of trial burns.

TABLE 4.2 Summary Data for Incineration of VX in the Liquid Incinerator at JACADS^a

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Requirement
Emissions Data						
VX effluent ^b	mg/m ³	<0.000057	<0.000054	<0.000060	<0.000066	<0.0003
DRE - VX	%	>99.9999997	>99.9999997	>99.9999997	>99.9999997	>99.99
Oxygen ^c	%	15.1	15.0	14.8	14.7	
Carbon dioxide ^c	%	3.8	4.0	4.1	4.3	
Carbon monoxide ^d	ppm	12.9	12.8	13.6	15.4	≤100 hourly average
Combustion efficiency	%	99.97	99.97	99.96	99.96	≥99.9
Particulate matter	mg/dsm ³	3.05	10.4	3.32	2.69	<180
corrected to 7% O ₂ ^e						
HCl Emissions	lb/h	<0.026	<0.025	<0.025	<0.027	<4
Operating Data						
Agent feed rate	lb/h	696	700	699	699	NA
Primary chamber	°F	2,676	2,705	2,721	2,730	NA
After-burner	°F	1,985	1,982	2,064	1,986	NA
Decon solution feed rate	gpm	3.03	3.31	3.34	3.19	NA
Process Stream Data						
Scrubber Brine	ppb	<20	<20	<20	<20	NA
Scrubber liquor	ppb	<20	<20	<20	<20	NA

^a Notation:

- DRE = destruction and removal efficiency
- gpm = gallons per minute
- lb/h = pounds per hour
- mg/dsm³ = milligram per dry standard cubic meter
- mg/m³ = milligram per cubic meter
- NA = not available.
- ppb = parts per billion
- ppm = parts per million.

^b Since VX was not detected in the emissions, table values represent the lower limit of quantification of the sampling and analysis methods used.

^c ORSAT analysis values.

^d Measured at the stack and corrected to 7% O₂ on a dry basis.

^e Average of the Method 5 acid train and Method 5 multiple metals train results.

Source: Southern Research Institute (1992a).

4.4 PERMEABLE SOLID MATERIALS – K903

4.4.1 Waste Description

Permeable solid material wastes are designated with the waste code K903 and include diverse types of materials, ranging from paper and rags to wood and personal protective suits. The wastes in this group are characterized by both surficial and internal (absorbed) chemical agent contamination. One of the major waste streams in this treatability group is DPE suits used in TOCDF and CAMDS that have been potentially exposed to chemical agent vapors and liquids. Also included in this waste treatability group are solid wastes from the laboratory, spill cleanup materials, trash/plastic waste, and other maintenance wastes. These items are typically chemically neutralized to remove agent contamination and meet LDR technology standards once chemical neutralization is complete. However, incineration may also be applied for the K903 waste stream to meet LDR treatment standards.

4.4.2 Applicability

Multiple-hearth and rotary-kiln incineration are considered applicable for treatment of most K903 wastes. In the multiple-hearth and rotary-kiln type of incineration, thermal energy is transferred to the solid waste in the primary chamber to volatilize or decompose the organic constituents. Reactions involving the conversion of the organic compounds to carbon dioxide, water, and other inorganic compounds are initiated in the primary chamber and completed in the secondary chamber by additional heat input in the presence of excess oxygen. Rotary-kiln and multiple-hearth incineration are applicable treatment methods for destroying organic compounds absorbed in solid materials. Incineration is currently used in industry for the treatment of permeable materials, including soils and wastewater treatment sludges that are contaminated with hazardous organic compounds, including organophosphorus insecticides, which are similar in chemical structure to the nerve agents.

4.4.3 Demonstration

Incineration is a demonstrated technology for the treatment of the K903 wastes on the basis of data from full-scale operations of the MPF and the DFS at JACADS and trial burns at TOCDF (UEC 1992; SRI 1992b; EG&G 1997). Several agent contaminated solid materials are approved inputs for incineration in the JACADS MPF. These materials include spent high-efficiency particulate air (HEPA)

and pre-filters, absorbents, polystyrene and polyethylene waste, and nonhalogenated plastics and rubber waste (including plastic tools, rubber protective gear, plastic/latex gloves, rubber hoses).

DPE suits, which are also defined as K903 waste, are not presently incinerated by the Army. The Army determined that because the DPE suits are made of chlorinated hydrocarbons, incineration could potentially produce dioxins and furans. A thermal desorption technology, in which dioxins and furans are not formed, is being pursued by the Army at CAMDS and may become an approved LDR technology in the future. Incineration of DPE suits is nevertheless a viable treatment option because it will result in reduction of the chemical agents to proposed LDR concentration-based standards.

A successful demonstration of the incineration of wood dunnage containing chemical agent has also been conducted at JACADS. The RCRA trial burn for the DUN incinerator at JACADS demonstrated the ability to destroy GB agent when wood dunnage along with polyethylene carboys having GB absorbed in cellulose was used as the feed material (Raytheon 1995). Table 4.7 summarizes the trial burn data from the JACADS DUN incinerator. The destruction efficiency for GB was reported as greater than 99.9999% (Table 4.7). Emissions of carbon monoxide, hydrogen chloride, and particulate matter were also within established requirements.

The main parameters that affect incineration performance for contaminants in permeable solid matrices include thermal conductivity, water content, and organic content of the waste. The type of materials expected to be designated as K903 wastes are considered to have thermal conductivities similar to those of other wastes treated by incineration in private industry. Incineration is considered applicable and demonstrated for wastes that have low water content and high organic content. Wastes being considered in the K903 category generally possess these characteristics. Additionally, incineration is currently used in private industry for the treatment of permeable materials, such as soils and sludges, that are contaminated with hazardous organic compounds.

4.4.4 Conclusion

The incineration of K903 wastes is applicable and demonstrated on the basis of the results of the trial burns at TOCDF and full-scale operation at JACADS.

TABLE 4.1 Summary Data for Incineration of HD in the Liquid Incinerator at JACADS^a

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Requirement
Emissions Data						
HD emissions ^b	mg/m ³	<0.0057	<0.0087	<0.0063	<0.0063	<0.03
DRE – HD	%	>99.999965	>99.999953	>99.999975	>99.999972	>99.99
Oxygen ^c	%	14.5	14.2	14.0	14.5	
Carbon dioxide ^c	%	4.6	4.7	4.6	4.4	
Carbon monoxide ^d	ppm	18.5	14.4	15.5	16.0	<100 hourly average
Combustion efficiency	%	99.96	99.97	99.97	99.96	
Particulate matter corrected to 7% O ₂ ^e	mg/dsm ³	1.41	3.22	2.86	2.76	<180
HCl emissions	lb/h	<0.0028	<0.0037	0.02	<0.0036	<4
Operating Data						
Agent feed rate	lb/h	848.82	956.62	1319.69	1178.63	NA
Primary chamber	°F	2,710	2,711	2,708	2,710	NA
After-burner	°F	2,024	2,008	2,015	2,002	NA
Decon solution feed rate	gpm	3.28	3.32	3.28	3.38	NA
Process Stream Data						
Scrubber brine	ppb	<200	<200	<200	<200	NA
Scrubber liquor	ppb	<200	<200	<200	<200	NA
Slag	ppb	-	-	-	<200 ^f	NA

^a Notation:

DRE = destruction and removal efficiency

gpm = gallons per minute

lb/h = pounds per hour

mg/dsm³ = milligram per dry standard cubic metermg/m³ = milligram per cubic meter

NA = not available.

ppb = parts per billion

ppm = parts per million.

Source: United Engineers and Constructors (1993).

^b Since agent was not detected in the emissions, table

values represent the lower limit of quantification of the sampling and analysis methods used.

^c ORSAT analysis values.^d Measured in the secondary chamber exhaust and corrected to 7% O₂ on a dry basis.^e Average of the Method 5 acid train and Method 5 multiple metals train results.^f One slag sample was tested at the end of the trial burn.

4.5 MISCELLANEOUS AQUEOUS AND NONAQUEOUS LIQUIDS – K904

4.5.1 Waste Description

Included in the K904 waste group are potentially contaminated waste aqueous materials (such as water) and nonaqueous materials (such as antifreeze, refrigerants, hydraulic fluids, lubricating oils, and fuel oils). These waste streams are expected to be contaminated at low levels and may also be treated with a chemical neutralization solution.

4.5.2 Applicability

Incineration is an applicable technology for treating aqueous and nonaqueous liquid wastes containing chemical agents. Incineration uses thermal energy under conditions of high temperature and pressure to destroy organic compounds.

4.5.3 Demonstration

Incineration will achieve the proposed LDR concentration-based standards for K904 wastes. As indicated previously, incineration is routinely used to treat spent neutralization solutions from agent neutralization on an industrial scale as part of the operations of TOCDF and JACADS. In addition, incineration is a full-scale treatment technology commonly used in private industry for aqueous and nonaqueous hazardous wastes.

As indicated previously, spent neutralization solution is being successfully treated in the secondary chamber of the LIC at TOCDF and JACADS. Spent neutralization fluids are used within the secondary chamber to cool the incinerator gas and are incinerated in the process. RCRA trial burns for the LIC at JACADS (SRI 1991, 1992a; UEC 1993) demonstrated destruction of liquid chemical agents HD, GB, and VX injected into the primary chamber, while neutralization solutions were being treated by injection into the LIC secondary chamber. These trial burns have satisfied the requirements for agent destruction efficiency and allowable stack concentrations of chemical agent. The TOCDF RCRA permit specifies that spent neutralization solution will be treated by incineration in the secondary chamber of the LIC.

The organic constituents expected in the aqueous wastes are considered easier to incinerate than the POHCs selected for the RCRA trial burns on the basis

of incinerability indices. POHCs for the RCRA agent trial burns and the surrogate trial burns (tetrachloroethylene and trichlorobenzene for the TOCDF LIC) were selected from a ranking of incinerability of organic hazardous constituents on the basis of heat of combustion (EPA 1983) and thermal stability (EPA 1989a). The POHCs represented the compounds that are most difficult to destroy. Successful destruction of the POHCs provides evidence that the incinerator can achieve similar performance for compounds that are more easily incinerated than the POHCs (EPA 1989a).

Incineration also is a demonstrated technology for nonaqueous liquid wastes. JACADS has successfully incinerated GB-contaminated hydraulic fluid in the LIC [Program Manager for Chemical Demilitarization (PMCD) Programmatic Lessons Learned (PLL) issue 95-21]. In addition, on the basis of incinerability indices (EPA 1983, 1989a), the organic compounds present in the nonaqueous wastes are considered easier to destroy than POHCs demonstrated to be destroyed in the JACADS and TOCDF trial burns. Additionally, incineration has been proven as a full-scale treatment technology commonly used in private industry for nonaqueous solvents and oils contaminated with organic compounds.

4.5.4 Conclusion

The trial burn data collected during the incineration of chemical agent in the LIC support the destruction of any residual chemical agent in the spent neutralization solution. On the basis of the DRE obtained for the trial burn POHCs, other organics present in the neutralization solution or other aqueous wastes that have similar or higher incinerability rankings are expected to be destroyed to similar levels. Therefore, incineration is an applicable and demonstrated LDR technology for treatment of aqueous wastes because proposed LDR treatment standards for K904 wastes will be met using this technology.

Waste oil, hydraulic fluids, and other nonaqueous organic liquid wastes have been successfully incinerated in private industry. Available incinerator data are transferable to this category because these wastes are compatible with incineration and would not be expected to hinder destruction of the chemical agent. Therefore, incineration is considered an applicable and demonstrated technology for treatment of nonaqueous liquid wastes.

4.6 SPENT CARBON – K905

4.6.1 Waste Description

The K905 waste group consists of spent activated carbon used in various filter systems. The main sources of spent carbon are the heating, ventilation, and air conditioning (HVAC) filter systems of the munitions demilitarization building, control room, personnel maintenance building, and laboratories. Activated carbon also is generated from the filters, on chemical agent tanks, from ACAMS filters, and from personnel respirators. Carbon is expected to contain a wide range of chemical agent concentrations depending on the source. Carbon from chemical agent tank filters may contain higher concentrations of agent than does the carbon from HVAC filters.

4.6.2 Applicability

Incineration is commonly used in private industry for treatment of activated carbon that has been used to adsorb chlorinated and nonchlorinated hazardous organic compounds. Some commercial incinerator facilities also provide the option of directly incinerating the shipping container containing the spent carbon.

4.6.3 Demonstration

Incineration is a demonstrated treatment technology for chemical agent contaminated carbon. Incineration is routinely used in full-scale industrial practice for the destruction of organic compounds adsorbed on carbon (EPA 1989b). Destruction of chemical agent itself is demonstrated on the basis of results of the current full-scale operations of the DFS at JACADS (SRI 1992b; EG&G 1997).

4.6.4 Conclusion

Performance data from the incineration of chemical agent contaminated spent carbon is not available; however, incineration of spent carbon contaminated with hazardous organics is routine practice in private industry. Incineration is considered an applicable and demonstrated technology for treatment of spent carbon and is capable of meeting proposed LDR concentration-based standards.

4.7 INCINERATOR RESIDUE WASTES – K906, K907, AND K908

4.7.1 Waste Description

The incinerator residue waste group consists of waste code groups K906 – ash, cyclone residue, and PAS baghouse dust from incineration; K907 – slag and refractory generated from incineration; and K908 – brine salts, liquids, and sludges from the BRA. All of these wastes are the result of incineration operations and therefore meet chemical agent LDR standards as generated.

4.7.2 Applicability

Incinerator residues meet LDR standards as generated and will not require further treatment unless the waste exhibits a RCRA characteristic.

4.7.3 Demonstration

As part of the trial burns conducted at JACADS, incinerator residue wastes were sampled and analyzed for chemical agent. No chemical agent was detected in the scrubber brine, LIC slag, MPF residue/ash, DFS HDC ash, or DFS cyclone residue (UEC 1992; SRI 1992b; EG&G 1997). Because the waste streams in this group would not normally contain agent above any proposed LDR treatment standards, they would not require treatment to reduce chemical agent levels. The results of the chemical agent analysis of incinerator residues during trial burns conducted at JACADS indicate that agent was below detection limits in all cases for ash, slag, and cyclone residue (see Tables 4.4, 4.5, and 4.6).

4.7.4 Conclusion

These wastes are incinerator residues, have been exposed to conditions that destroy chemical agent, and meet LDR treatment standards as generated.

5 TREATABILITY GROUPS

Data presented in Section 4 relate specifically to incineration of the chemical agents GB, VX, and HD, which are the major components of the Army's chemical stockpile in the State of Utah. Available data on the incineration of the other hazardous constituents, which are listed in Table 1.1 (Section 1), are limited. However, with the exception of DM and BZ, the other chemicals can be placed in treatability groups.

Treatability groups are groups of chemicals or wastes that are similar in terms of physical and chemical characteristics. Data available for one or more chemicals or wastes in the treatability group can be used to support LDR standards for the other chemicals or wastes in the same treatability group. A similar concept was used by EPA in developing the LDR program. As is the case for chemical agents and associated wastes, EPA did not have treatment data for all the hazardous wastes constituents in all the waste matrices necessary to develop LDR standards, and, so, relied on establishing treatability groups for all the hazardous wastes regulated under the RCRA program. In accordance with this concept, hazardous wastes included in the UCAR can be considered to be in two basic treatability groups: (1) nerve agents and (2) blister agents.

5.1 NERVE AGENTS

The nerve agent treatability group consist of the G-agent and the V-agent series (and associated compounds) as listed below:

- G-series: GA, GB, GD, and GF
- V-series: VX, Vx, and EA2192

Three chemicals in the G agent series, GB, GD, and GF, differ only in molecular structure by an alcohol grouping, i.e. o-isopropyl, o-pinacolyl, and cyclohexyl, respectively. The chemical agent GA has a cyanide moiety rather than fluorine, otherwise it is structurally similar to the others in the G-series. As shown by the data presented in Section 4, the chemical agent GB is readily destroyed by incineration to meet the proposed LDR concentration-based treatment standards. Because of similar molecular structure as shown in Appendix A, all the chemical agents in the G-series are expected to meet the proposed LDR concentration-based treatment standards when incinerated.

The two chemical agents in the V-series, VX and Vx, have identical molecular weights. The difference is that VX has ethyl groupings while Vx has an isobutyl group, as shown in the structures presented in Appendix A. EA2192 is a degradation product that is formed by the cleavage of an ethoxy group from VX. As shown in the data presented in Section 4, the chemical agent VX is readily destroyed by incineration to meet LDR concentration-based treatment standards. Because of similar molecular structure, as shown in Appendix A, the chemical agent Vx and the degradation product EA2192 in this series are expected to meet LDR treatment standards when incinerated.

5.2 BLISTER AGENTS

The blister agent treatability group consists of the chemical agents in the H-series and L-series and a mixture of a chemical from each of the two series, HL, as listed below:

- H-series: H, HD, HN1, HN3, Q, T, and the mixtures HT and HQ
- L-series: L or L1, L2, L3, and LO
- Mixture HL

In the H-series, H and HD are the same chemical. The HD has a higher purity in that it is distilled H; they are both commonly referred to as mustard gas. HN1 and HN3 are nitrogen mustards; the sulfur molecule is replaced by nitrogen. The difference between the nitrogen mustards is that HN1 has an ethyl grouping, while HN3 has an ethyl grouping with a chlorine molecule. The Q and T in the series are longer-chain mustards that were added to H to lower the freezing point. As shown in Section 4, HD is readily destroyed by incineration to meet the proposed LDR concentration-based treatment standard. Also, mustard gas and nitrogen mustard have been assigned a thermal stability index of 132-134, Class 4, in EPA's Volume II of the Hazardous Waste Incineration Guidance Series (EPA 1989a). This guidance series lists relative destruction efficiencies of the principal organic hazardous constituents (POHCs); the mustards are about midway in the listing. Because of similar molecular structure to H/HD, the Q and T, as well as the mixtures HT and HQ are expected to meet the proposed LDR concentration-based treatment standards when incinerated.

The chemicals in the L-series, except LO, are isomers and thus all have the same molecular weight. LO is a hydrolysis product that is formed rapidly when lewisite 1 is exposed to water or water vapor. Although the destruction of lewisite by incineration has not been studied extensively by the Army, it appears that the

proposed LDR treatment standards from the aspect of lewisite destruction would be met. However, the arsenic that is part of the lewisite molecule would not be destroyed during the destruction process. This situation has been recognized by the EPA as indicated in Section 3.3 above, and further treatment would be required to remove the arsenic or to stabilize the affected waste streams. As stated in Section 2.2.2.1, the Army has opted to use a neutralization system to destroy the stockpile of lewisite. An LDR standard of stabilization is proposed for the spent chemical neutralization fluid from treatment of lewisite because of the sodium arsenate content of the fluid. EPA's LDR standards for arsenic would also be applied if the spent neutralization fluid exceeds EPA's RCRA toxicity characteristic for arsenic.

The mixture of HL is similar to the L-series in that if destroyed by incineration it would also appear to meet the proposed LDR treatment standards from the aspect of mustard and lewisite destruction. However, also like the L-series, the waste stream residuals would require analysis and/or treatment for arsenic contamination if the RCRA toxicity characteristic is exceeded for arsenic. Incineration or chemical neutralization followed by stabilization is proposed for the HL waste stream.

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6 CONCLUSIONS

Because it would meet or exceed the proposed LDR concentration-based treatment standards, incineration is considered an established and demonstrated treatment technology for each of the waste groups as discussed above. Incineration has been demonstrated in JACADS, CAMDS, and TOCDF. TOCDF has received a permit from the State of Utah to operate as a chemical agent disposal facility. Finally, incineration is commercially practiced as a full-scale LDR treatment technology.

Available data presented in Section 4 provide evidence that incineration results in destruction of the constituents of concern in the specific waste matrices discussed in this report. Available trial burn data demonstrate that chemical agents GB, HD, and VX were substantially destroyed (with typical destruction efficiencies of greater than 99.9999%), and it can be considered demonstrated for other similar chemical agents and in other waste matrices as defined in Section 3. In all cases, chemical agent was destroyed to nondetectable levels in the stack and process residuals. Process residuals do not require any further treatment for chemical agents.

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7 REFERENCES

CAMDS: See Chemical Agent Munitions Disposal System.

Chemical Agent Munitions Disposal System, 1996, *Test Report for Chemical Agent (VX, GB, and HD) 5X Decontamination Verification*, Test Report No. 32-57a, March.

DA: See Department of the Army.

Department of the Army, undated, "Toxic Chemical Safety Standards," DA PAM 385-61, undated draft.

Edgerton, Germehausen, and Grier Defense Materials, Inc., 1997, *RCRA Agent GB Trial Burn Report for the Deactivation Furnace System (DFS)*, April 9.

EPA: See U.S. Environmental Protection Agency.

Holmes & Narver, Inc., 1982, *JACADS Facility Criteria Development*, Vol. II, Report 4505-TR-11, April.

National Research Council, 1984, *Disposal of Chemical Munitions and Agents*, Committee on Demilitarizing Chemical Munitions and Agents, National Academy Press, Washington, D.C.

National Research Council, 1994, *Evaluation of the Johnston Atoll Chemical Agent Disposal System (JACADS) Operational Verification Testing, Part II*, Committee on Demilitarizing Chemical Munitions and Agents, National Academy Press, Washington D.C.

NRC: See National Research Council.

Raytheon Engineers and Constructors, Inc., 1995, *RCRA Trial Burn Report for Agent GB/Dunnage in the Dunnage Incinerator at the JACADS*, March.

Southern Research Institute, 1991, *Results of the RCRA Trial Burn with GB Feed for the Liquid Incinerator at the JACADS*, SRI-APC-91-190-6967-006-F-R4, June 17.

Southern Research Institute, 1992a, *Results of the RCRA Trial Burn with VX feed for the Liquid Incinerator at the JACADS*, Final Report, SRI-APC-92-384-7530.11.1.-I-R3, June 23.

Southern Research Institute, 1992b, *Results of the RCRA Trial Burn and TSCA Demonstration Burn of the Deactivation Furnace System with M55 VX Rockets at the JACADS*, Final Report, SRI-APC-92-385-7530.5.1-I-R3, June 23.

SRI: See Southern Research Institute.

TOCDF: See Tooele Chemical Agent Disposal Facility.

Tooele Chemical Agent Disposal Facility, 1997, *Waste Analysis Plan, Version 3*, TOCDF WAT02 0117, April.

UEC: See United Engineers and Constructors.

United Engineers and Constructors, 1992, *RCRA Trial Burn Report for HD - Mustard Ton Containers - Metal Parts Furnace at the JACADS*, Dec. 16.

United Engineers and Constructors, 1993, *Results of the Demonstration Test Burn for Thermal Destruction of Agent HD in the JACADS Liquid Incinerator*, Feb.

U.S. Environmental Protection Agency, 1983, *EPA Guidance Manual for Hazardous Waste Incineration Permits*, Washington, D.C.

U.S. Environmental Protection Agency, 1988a, *Methodology for Developing Best Demonstrated Available Technology (BDAT) Treatment Standards*, Office of Solid Waste, Washington, D.C.

U.S. Environmental Protection Agency, 1988b, *BDAT Background Document for K037*, Office of Solid Waste, Washington, D.C.

U.S. Environmental Protection Agency, 1989a, *EPA Guidance on Setting Permit Conditions and Reporting Trial Burn Results*, Volume II of the Hazardous Waste Incineration Guidance Series, Washington, D.C.

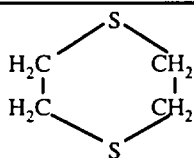
U.S. Environmental Protection Agency, 1989b, *Treatment Technology Background Document*, EPA/530-SW-89-048A, Washington, D.C., June.

U.S. Environmental Protection Agency, 1994, *BDAT Background Documentation for Universal Standards*, Washington, D.C.

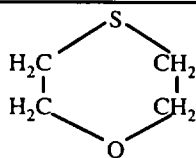
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APPENDIX A:
CHEMICAL STRUCTURES DICTIONARY

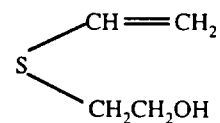
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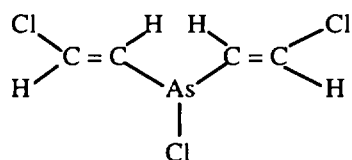
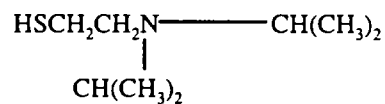
1,4 - Dithiane



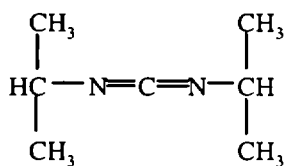
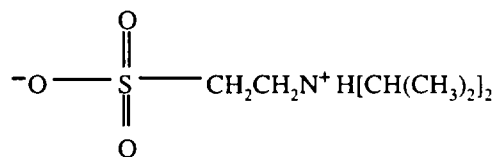
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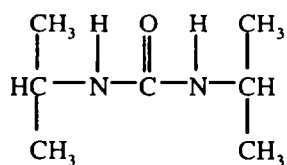
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or L-2

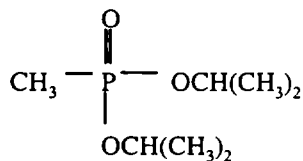
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Carbodiimide

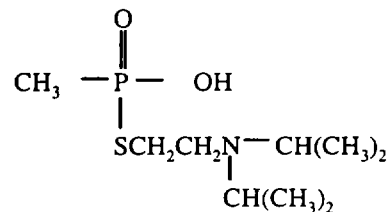
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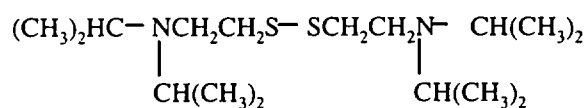
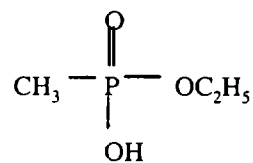
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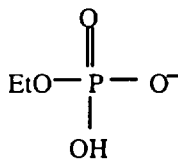
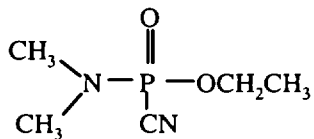
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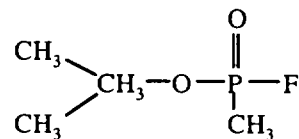
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EA 4196 OR (DES)₂

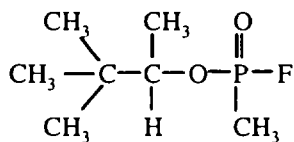
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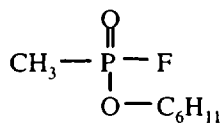
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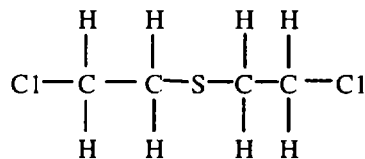
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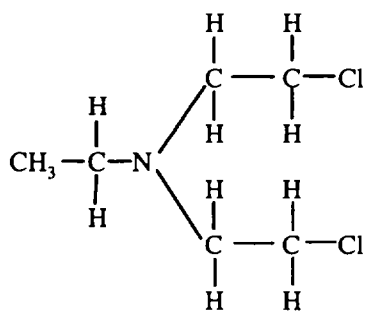
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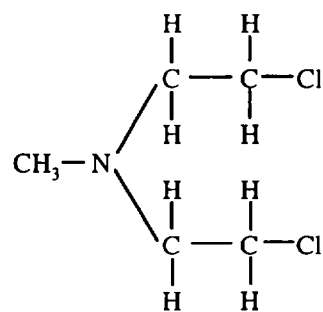
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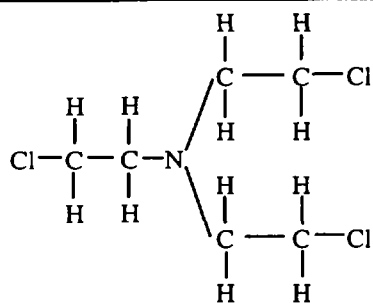
H/HD



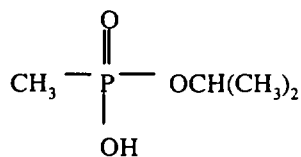
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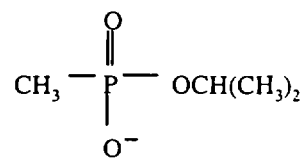
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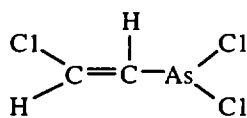
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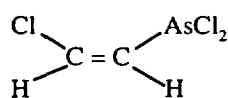
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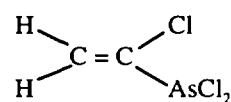
IMPA Anion



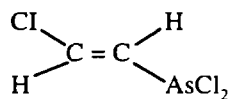
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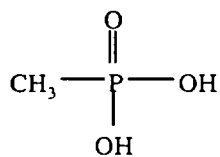
cis-Lewisite



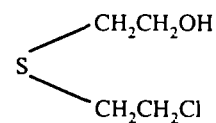
geminal-Lewisite



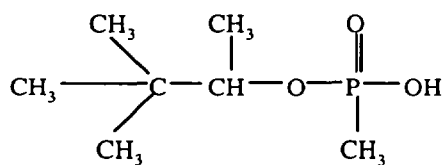
trans-Lewisite



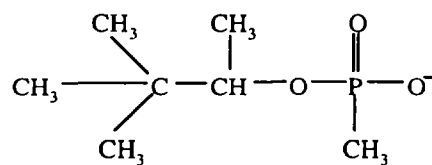
MPA



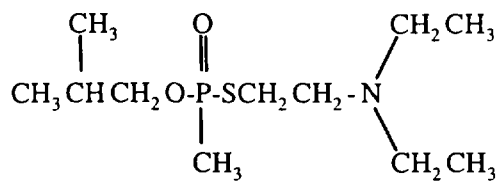
Mustard Chlorohydrin



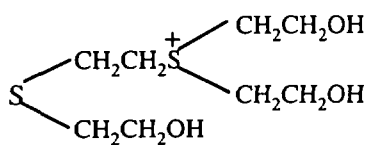
Pinacolylmethyl phosphonic acid



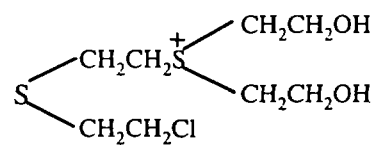
Pinacolylmethyl phosphonic acid anion



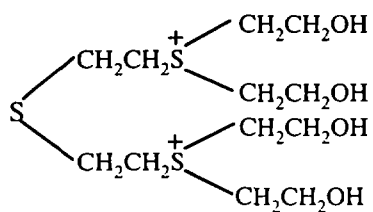
Vx



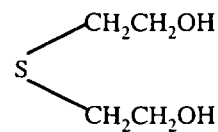
CH-TG



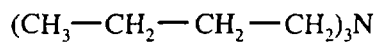
H-TG



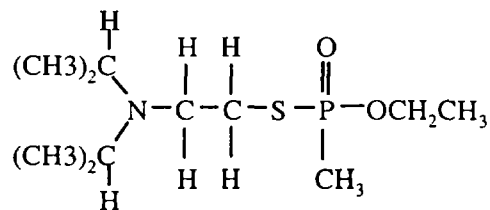
H-2TG



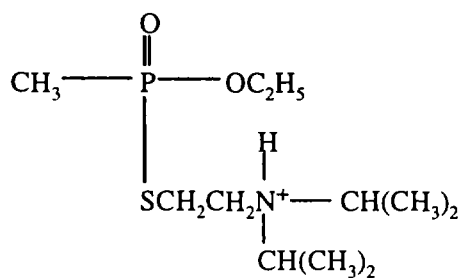
Thiodiglycol



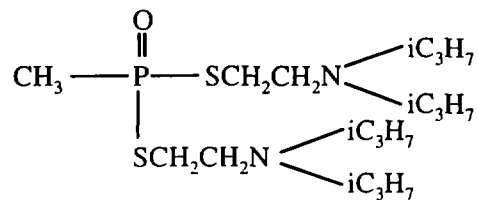
Tributylamine



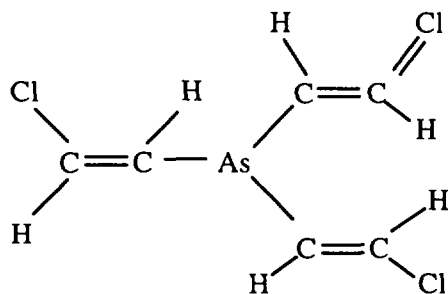
VX



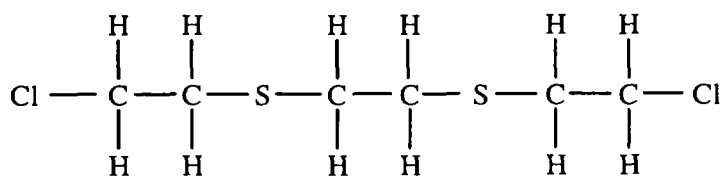
Protonated VX



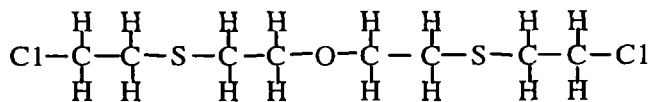
"Bis Impurity" in VX



L-3 or Tris(2-chlorovinyl) arsine



Q



T

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